User Interface of the CatSim Model and Practical Guidelines

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Contents

How to Use This Manual

This user manual should help performing a CatSim analysis for a specific country. The policy applications of the CatSim tool can provide insights on the development and use of indicators of vulnerability, resilience, coping capacity and other concepts important for policy interventions with regard to disasters and other global-change phenomena. The CatSim tool relies on quantitative indicators. Risk is estimated making use of historical statistics and exposure; financial resilience is estimated with an index of observations on the financial preparedness of the government; financial vulnerability is a composite of the two and is measured in terms of the financing gap. Clearly financial vulnerability of the public sector presents only one aspect, albeit an import one, of vulnerability to natural hazards. Other indicators are necessary in order to complement this concept. Furthermore, participation and transparency in the design, estimation and use of vulnerability indicators is essential for their legitimacy. As there is a substantial degree of uncertainty in estimates of disasters risks and financial vulnerability, it is important that users have full participation in their design, estimation and use. CatSim has been created as a participatory, interactive tool for building capacity of policy makers by sensitizing them to the tradeoffs inherent in planning for disasters.

Users which do not have any background knowledge on public sector risk management should start with Chapter 1 which gives a basic introduction into the issue (with focus on the CatSim approach). People who are already familiar with CatSim or public sector risk management may skip Chapter 1 and go directly to Chapter 2 which describes CatSim briefly and discusses all the important steps to make for a full analysis. Chapter 3 gives a full list of all input parameters, its meaning as well as how to estimate them. It is recommended for an inexperienced user to take first a close look at the variables to avoid any misunderstandings in the later chapters. It is also recommended, if available, to use the accompanied risk report (e.g. referred to as the Madagascar risk report) for more details on how the variables are estimated. Chapter 4 then describes all user interfaces in CatSim in all the necessary detail. In Chapter 5 a typical CatSim run is discussed which could be the starting point for more advanced users. In case of interpretation problems of the results one should use Chapter 6, where a full CatSim analysis is performed and various issues are discussed. Finally, Chapter 7 gives recommendations how to calibrate the results if specific qualitative knowledge is available which was not incorporated in the quantitative estimation procedures. It is recommended to do this in every CatSim analysis to calibrate the expected growth trajectories and financing resources one has without disaster events (which could be based on other macroeconomic models or expert knowledge)

1. General Introduction to Public Sector Risk Management[1]

The number and losses of natural disasters have been increasing globally due to such factors as increases in wealth, population growth and migratory trends from rural to urban areas and possibly climate change with limited evidence as of today. Whereas more developed countries usually are able to cope with the impacts of disasters, in less developed countries often a large proportion of the population is severely affected and a substantial strain is posed on a country's resources and ability to finance important social and economic programs. There, losses historically have been financed by relying on diversions from the budget, already allocated loans and donations from the international community. Currently, more and more emphasis is put on financial planning before events. In addition to mitigating potential losses and preparing for potential events, the financial planning and management of risk has become an important element of disaster risk management.

The state, or government, plays a major post-disaster role in reducing long-term economic repercussions by repairing damaged infrastructure and providing financial assistance to households and businesses. If critical infrastructure is not repaired in a timely manner, there can be serious effects on the economy. The repair of public infrastructure can be a significant drain on public budgets especially in developing and transition countries. In Poland, for example, public infrastructure damage from the 1997 floods amounted to 41% of the reported direct losses (Kunreuther and Linnerooth-Bayer, 2003). The Polish government absorbed close to half of these losses, which increased its budget deficit substantially. Governments of disaster-prone countries, for example, Honduras, the Philippines, Mexico and regions in China, face such large liabilities in repairing their critical infrastructure and providing subsistence to disaster victims that without international assistance they can be set back years in their development. After Hurricane Mitch devastated Honduras in 1998, GDP growth in the following year (despite the growth impetus from reconstruction) dropped from an estimated 3.3% to -1.9% (Mechler, 2004). Typically disasters affect government budgets by reducing tax revenue, increasing fiscal deficits and worsening trade balances (Otero and Marti, 1995). Governmental support of relief and reconstruction is critically important for economic recovery and ultimately preventing the long-term hidden deaths and suffering from disasters.

Especially in highly exposed developing countries, the state can be physically and financially vulnerable to natural disasters, what we refer here to as *public sector financial vulnerability*. Including international aid and loans, developing country governments frequently lack the liquidity to fully repair damaged critical public infrastructure or provide sufficient support to households and businesses for their recovery. For example, following the 2001 earthquake in the state of Gujarat, India, funds for recovery from the central government and other sources fell far short of promises, and actual funding only

[1] Based on Hochrainer 2006 and Mechler et al. 2006

covered around 30% of the state government's needed recovery funds (World Bank, 2003**).**

Recent cases of government post-disaster inability to finance necessary relief and reconstruction activities have sounded an alarm, prompting financial development organizations, such as the World Bank, among others, to call for greater attention to reducing financial vulnerability and increasing the resilience of the public sector (Pollner, 2001; Gurenko, 2004). In this context, *resilience* refers to the capacity of a social system to absorb economic disturbance and reorganize, or to "bounce back" so as to retain essentially the same function, structure and identity (Walker, et al. 2002).

This chapter addresses the financial vulnerability of developing country governments to disasters of natural origin, and examines pre-disaster (ex ante) financial measures for increasing the coping capacity and resilience of the public sector. In the next sub-sections, a framework of public sector financial vulnerability and its components of economic risk and financial resiliency is discussed, along with measurable indicators of these concepts.

1.1. Public Sector Financial Vulnerability

Turner, et al (2003) define vulnerability as the degree to which a system or subsystem is likely to experience harm due to exposure to a hazard, either as a perturbation or stressor. Some communities suffer less harm than others from hurricanes, fires, floods and other extreme events because they can mitigate the damage and recover more rapidly and completely. As a case in point, Bangladesh has become less physically vulnerable to cyclones. Over the past four decades deaths from cyclones in Bangladesh have decreased by two orders of magnitude as people have learned to respond to warnings and use storm shelters. Moreover, the people in Bangladesh may become less economically vulnerable to the long-term economic losses from cyclones and other disasters as affordable micro-insurance and other financial hedging instruments become available (Bayer and Mechler, 2005).

In the literature, work on economic vulnerability to external shocks (often of small island developing states) has focused on the structure of an economy (e.g. commodity-based versus high-technology), the prevailing economic conditions (e.g. degree of inflation, economic recession) and the general stage of technical, scientific, and economic development (Benson and Clay 2000). Economic vulnerability is assessed by a set or a composite index of indicators such as the degree of export dependence, lack of diversification, export concentration, export volatility, share of modern services and products in GDP, trade openness or simply GDP (Briguglio, 1995; Commonwealth Secretariat, 2000).

CATSIM focuses on the financial vulnerability of the public sector as a subset of economic vulnerability, which is defined as the degree to which a public authority or government is likely to experience a lack of funds for financing post-disaster reconstruction investment and relief. Financial vulnerability depends on the asset risks the country is facing from natural hazards, which can be measured by the *hazard* frequency and intensity, the public and private capital *exposure* and the *sensitivity* of the public and private assets to the hazard. A second important component to financial vulnerability is the *resilience* or financial capacity of the public authorities to cope with the losses. This can be measured by the available financial resources for meeting unexpected liabilities of the public sector. If the government has sufficient reserves or insurance cover to finance its post-disaster liabilities, or can easily raise capital through its budget or borrowing, then it is financially resilient to the disaster shock. However, if the asset risks are high and the government cannot cover the anticipated losses, then a *financing gap* may occur. The financing gap is an indicator of financial vulnerability. The term financing gap has been defined in the economic growth modeling literature as the difference between required investments in an economy and the actual available resources. The main policy recommendation consequently has been to fill this gap with foreign aid (Easterly, 1999).[2] Here, this tradition is followed and the financing gap is understood as the lack of financial resources to restore assets lost due to natural disasters and continue with development as planned.

An assessment of public sector financial vulnerability, or the financing gap, thus, considers the following two questions:

- Given the country's current exposure to hazards and changes in future conditions, what are the government's capital asset *risks* over the planning period?
- Given the government's financial situation and history of external assistance, is it financially *resilient* to these disasters in the sense of being able to access sufficient post-disaster funding opportunities to cope with losses and liabilities?

Direct asset risk and *financial resilience* are thus essential concepts for addressing public sector financial vulnerability to natural disasters. Public policy measures can focus on reducing risks by reducing exposure, e.g., with structural measures or land-use planning, or by reducing the sensitivity of structures, e.g., by seismically retrofitting the public infrastructure. In addition, policies can improve the resilience of the private or public sectors, e.g., by developing appropriate systems for insuring or transferring the risks. To reduce their financial vulnerability, public authorities should consider investing both in risk reduction as well as financial instruments for assuring fiscal solvency. In what follows, we discuss these concepts with reference to how they can be assessed and measured.

[2] This approach has been criticized among others by Easterley 1999 as over-simplistic and generally lacking to account for the role of incentives and institutions in economic growth. Nevertheless, capital investment has been shown to be an important driver of economic growth.

Direct asset risk: hazard, exposure and sensitivity

Risk is generally defined as the probability and magnitude of an adverse outcome, and includes the uncertainty over its occurrence, timing, and consequences (Covello and Merkhofer, 1993). Risks of extreme events can be characterized by the frequency and intensity of the events, as well as the exposure and sensitivity of physical assets. A common measure is the probabilistic loss exceedance curve, which indicates the probability of certain losses exceeding a certain amount, eg. there is a 1% probability (called a 100 year event) that losses may exceed 1 billion US$

Financial Resilience

Originating in the field of ecology, a key concept in vulnerability research is *resilience*, which refers to the capacity of a system to absorb disturbances and reorganize so as "bounce back" to essentially the same function and structure (Walker, et al. 2002).

> A resilient ecosystem can withstand shocks and rebuild itself when necessary. Similarly, a resilient social system, in our case the public sector, can absorb shocks and rebuild the economy such that the country or region stays on a similar economic trajectory.

Systems with high resiliency are able to re-configure themselves without significant declines in crucial functions in relation to primary productivity and economic prosperity. Resilience in social systems has the added capacity of humans to anticipate and plan for the future.

Because of the role of the public sector in financing reconstruction, financial preparedness is essential for countries or regions to "bounce back" from major shocks. The preparedness of the public authorities for financing disasters depends on their access to capital after a disaster, which, in turn, depends on, among other fiscal indicators, the government's tax base, budget deficit, and internal and external debt. In addition, regional governments of developing countries rely extensively on national and international loans and aid. Despite often generous international support, developing countries often encounter shortfalls in financing reconstruction and relief post-disaster. One example mentioned above is the earthquake of 2001 in the state of Gujarat in India, where planned funding from government relief funds, bi-and multilateral sources and budget diversions would have exceeded planned expenditure; however actual funding disbursed amounted to only 32% of the planned amount (World Bank, 2003). As shown in Figure 1, the Gujarat government experienced a severe *financing gap* with regard to the planned expenditures for repairing the housing stock and public infrastructure as well as providing relief to the affected population.

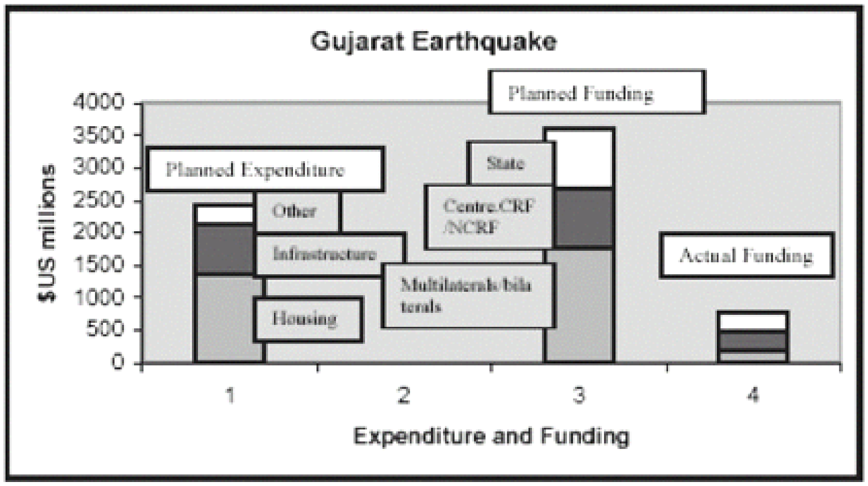


Fig. 1: Financing gap in India after Gujarat earthquake.
Source: World Bank 2003: 22.

Financial preparedness can be enhanced with pre-disaster planning. The public authorities can set aside reserves in a catastrophe fund (such funds exist in India), or, alternatively, they can purchase instruments that transfer their risk to a third party. Insurance is the most common pre-disaster instrument, but recently other types of novel risk-transfer instruments have emerged. These instruments and their costs will be discussed in more detail in the next section. The important message is that pre-disaster measures exist to improve sovereign financial resilience for highly exposed countries. Given that these measures are costly, it is important to ask what countries need them (what countries are financially vulnerable?) and what are their costs and benefits? These questions are addressed by the CATSIM model as described in the following section.

1.2. Assessing Financial Vulnerability with the CATSIM tool

Risk and resilience are essential for addressing public sector financial vulnerability to natural disasters. Public policy measures can focus on reducing risks by reducing exposure, e.g., with structural measures or land-use planning, or by reducing the sensitivity of structures, e.g., by seismically retrofitting the public infrastructure. In addition, policies can improve the resilience of the private or public sectors, e.g., by developing appropriate systems for insuring or transferring the risks. To reduce their financial vulnerability, public authorities should consider investing both in risk reduction as well as financial instruments for assuring fiscal solvency.

The experience of India and many other disaster-prone developing countries raises the question of how policy makers can reduce public sector financial vulnerability. The IIASA CATSIM tool was developed to provide insights on this question (for a detailed discussion of CATSIM see Hochrainer et al., 2004; Freeman et al., 2002). CATSIM uses Monte

Carlo simulation of disaster risks in a specified region and examines the ability of the government to finance relief and recovery. It is interactive in the sense that the user can change the parameters and test different assumptions about the hazards, exposure, sensitivity, general economic conditions and the government's ability to respond. CATSIM can provide an estimate of a country's or region's public sector financial vulnerability. As a capacity building tool, it can illustrate the tradeoffs and choices the authorities confront in increasing their resilience to the risks of catastrophic disasters. The CATSIM methodology consists of five stages or modules as described below and illustrated in Figure 2.

Stage 1: The risk of direct asset losses expressed in terms of their probability of occurrence and destruction in monetary terms is assessed with historical data. Risk is modeled as a function of hazard (frequency and intensity), the elements exposed to those hazards and their physical sensitivity.

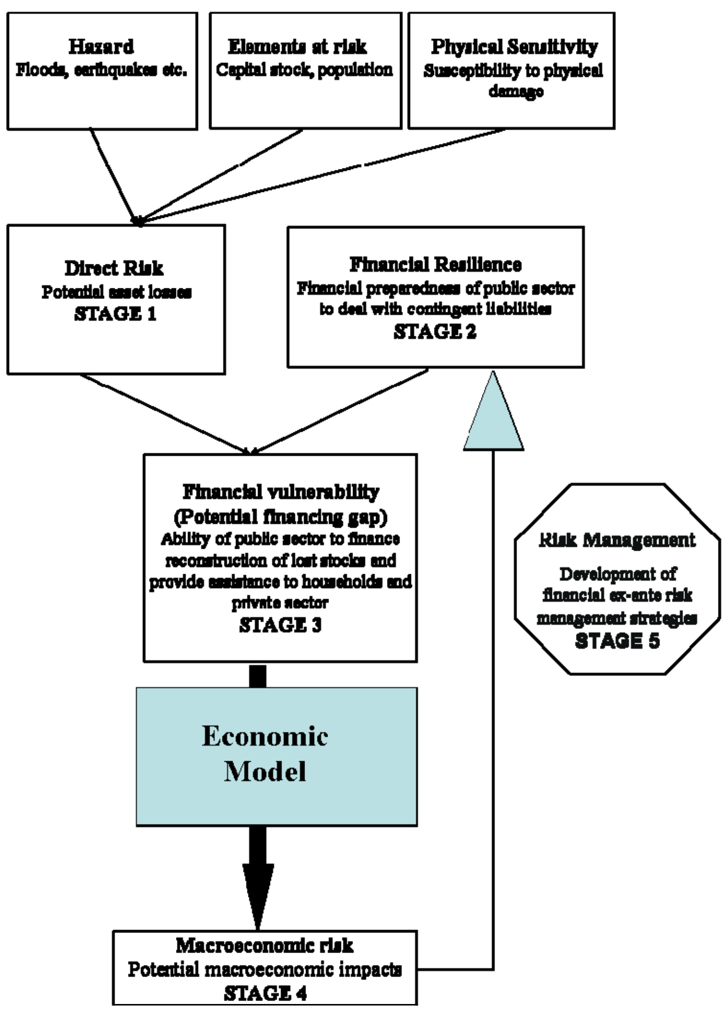


Fig. 2: Financial vulnerability and the CATSIM methodology

Stage 2: The financial preparedness of the public sector to the direct losses is assessed. Financial preparedness is a measure of financial resilience and can be defined as the access of the state or central government to funds for financing reconstruction of public infrastructure and the provision of relief to households and the private sector. Financial preparedness will, in turn, depend on the general economic conditions of the country.

Stage 3: Financial vulnerability, measured in terms of the financing gap, is assessed by simulating the risks to public infrastructure and the financial resilience of the government to cover its post-disaster liabilities following disasters of different magnitudes.

Stage 4: The consequences of a financing gap on the macroeconomic development of the country are characterized with indicators, such as economic growth or the country's external debt situation. These consequences represent the impacts on the economic flow variables as compared to the impacts on stocks addressed by the asset risk estimation in stage 1.

Stage 5: Strategies are developed and illustrated that build financial resilience of the public sector.

Stage 1: Assessing public sector risk

The stage 1 CATSIM module assesses the risk of direct losses in terms of the probability of asset losses in the relevant country or region. Consistent with general practices, risk is modeled as a function of hazard (frequency and intensity), the elements exposed to those hazards and their physical sensitivity (Burby, 1991; Swiss Re, 2000). [3] In more detail,

- Natural hazards, such as earthquakes, hurricanes, or floods, are described by their intensity (e.g. peak flows for floods) and recurrency (such as a 1 in 100 year events i.e. with a probability of 1%).
- Exposure of elements at risk: Total private and public capital stock is estimated.
- Physical sensitivity describes the degree of damage to the capital stock due to a natural hazard event. The method commonly used here are fragility curves setting the degree of damage in relation to the intensity of a hazard.

Based on data on the return period and losses in percent of capital stock, CATSIM generates loss frequency distributions describing the probability of specified losses occurring, such as a 100 year event causing a loss of 200 million USD of public assets, a

[3] In the hazards and risk community, "sensitivity" is referred to as "vulnerability", and often exposure is included in the sensitivity component; thus, risk is defined by hazard and vulnerability. In catastrophe models carried out for insurance purposes, the contract specifications of the underwritten and exposed portfolios are added as a fourth component (eg. Swiss Re 2000).

50 year event causing a 40 million USD loss, and so on.[4] It should be kept in mind that top-down estimates at this broad scale are necessarily rough. Since most disasters are rare events, there is often little in terms of historical data; furthermore it is difficult to include dynamic changes in the system, for example, population and capital movements and climate change.

Stage 2: Assessing public sector financial resilience

Based on the information on direct risks to the government portfolio, financial resilience can be evaluated by assessing the government's ability to finance its obligations for the specified disaster scenarios. Financial resilience is directly affected by the general conditions prevailing in an economy, i.e., changes in tax revenue have important implications on a country's financial capacity to deal with disaster losses.

The specific question underlying the CATSIM tool is whether a government is financially prepared to repair damaged infrastructure and provide adequate relief and support to the private sector for the estimated damages of a 10- 50- 100- and 1000-year event? For this assessment, it is necessary to examine the government's sources, both sources that will be relied on (probably in an ad hoc manner) after the disaster and sources put into place before the disaster (ex ante financing). These sources are described below.

Ex post financing sources

The government can raise funds *after* a disaster by accessing international assistance, diverting funds from other budget items, imposing or raising taxes, taking a credit from the Central Bank (which either prints money or depletes its foreign currency reserves), borrowing by issuing domestic bonds, borrowing from the IFIs and issuing bonds on the international market (Benson, 1997; Fisher and Easterley, 1990). Each of these financing sources can be characterized by costs to the government as well as factors that constrain its availability, which are assessed by this CATSIM module. Sources not considered feasible are not included in the module.

As shown in Table 1, ex post financing is constrained, for example, disaster taxes are expensive to administer and generally not part of the public sector financing portfolio. In addition, borrowing is constrained, and CATSIM assumes that the sum of all loans cannot exceed the so-called *credit buffer* for the country. In the Highly Indebted Poor Countries Initiative (HIPC) the credit buffer is defined as 150% of the typical export value of this country minus the present value of existing loans (HIPC, 2002). These ex post instruments have (sometimes high) associated costs; even budgetary diversions have associated opportunity costs in terms of other government investments like building highways or schools.

[4] It is standard practice to refer to 20-, 50-, 100-, 500- and 1000-year events.

Table 1: Ex Post Financing sources for relief and reconstruction

Type	***Source***	***Considered in model***
Decreasing government expenditures	Diversion from budget	X
Raising government revenues	Taxation	-
Deficit financing *Domestic*	Central Bank credit	-
	Foreign reserves	-
	Domestic bonds and credit	X
Deficit financing *External*	Multilateral borrowing	X
	International borrowing	X
	Aid	X

Ex ante financing sources

In addition to accessing ex post sources, a government can arrange for financing before a disaster occurs. Ex ante financing options include reserve funds, traditional insurance instruments (public or private), alternative insurance instruments, such as catastrophe bonds, or arranging a contingent credit. In a reserve fund arrangement, the government sets aside funds which accumulate in years without catastrophes, and, in the case of an event, the accumulated funds can be used to finance reconstruction and relief. A catastrophe bond (cat bond) is an instrument whereby the investor receives an above-market return when a specific catastrophe does not occur, but shares the insurer's or government's losses by sacrificing interest or principal following the event. Contingent credit arrangements call for the payment of a fee for the option of securing a loan with pre-arranged conditions after a disaster. Insurance and other risk-transfer arrangements provide indemnification against losses in exchange for a premium payment. Risk is transferred from an individual to a (large) pool of risks. These ex-ante options can involve substantial annual payments and opportunity costs; statistically the purchasing government will pay more with a hedging instrument than if it absorbs the loss directly.

Given the costs, the question whether public sector insurance is desirable for improving financial preparedness is a question many developing country governments are asking. According to an early discussion by Arrow and Lind (1970) governments should generally not purchase insurance since the government portfolio due to the large number of public assets in different locations will exhibit sufficient diversification and post-disaster expenses can be spread over a large base of taxpayers. This means that the public authorities are not risk averse and therefore do not need to purchase insurance or other financial hedging instruments. Disaster risks and other stochastic shocks to public budgets can thus be ignored in public planning and budgeting decisions. Recent research undertaken however, has shown that the Arrow-Lind theorem does not hold for hazard-prone developing countries if they are facing high risks, if the pool of publicly owned assets is too narrow for sufficient diversification, and if they cannot raise sufficient funds after a disaster to finance the recovery process (Freeman et al., 2002a; Mechler, 2004, Hochrainer and Pflug 2009). Whether insurance is desirable for a developing country government will thus depend on the government's financial vulnerability and the cost of insurance instruments compared to the cost of other financing options.

The government's portfolio of ex ante and ex post financial measures is critically important for the recovery of the economy should a disaster occur. For this reason, an assessment of the government's asset risk and financial resilience is an essential part of disaster risk management. An IIASA study has carried out such an assessment for four highly at risk Latin American countries: Bolivia, Colombia, the Dominican Republic and El Salvador (Freeman et al., 2002b). The study revealed differences in their financial preparedness for disasters. At the time of the study, none of the four countries had ex ante instruments in place, like reserve funds or insurance. Bolivia and Colombia were, however, better prepared than the Dominica Republic and El Salvador to meet their liabilities within their current budget by diverting from other planned investments. Colombia, alternatively, was far more constrained with respect to other ex post options, such as borrowing domestically and internationally. These indicators of financial resilience can be combined with the risk each country is facing to yield an indicator of financial vulnerability. The results are discussed below.

Stage 3: Measuring financial vulnerability by the "financing gap"

Comparing available financing with the government's post-disaster financial obligations yields an estimation of the potential *financing gap.* In the IIASA study, the financing gap for Bolivia, Colombia, the Dominican Republic and El Salvador was assessed for a range of probabilistic disaster losses. Figure 3 illustrates this gap only for the 100 year event in each country. In this figure, the financing sources available to the governments of the four countries are compared with the governments' potential financial obligations calculated for the 100-year disaster. The shortfall between financial sources and obligations is the financing gap.

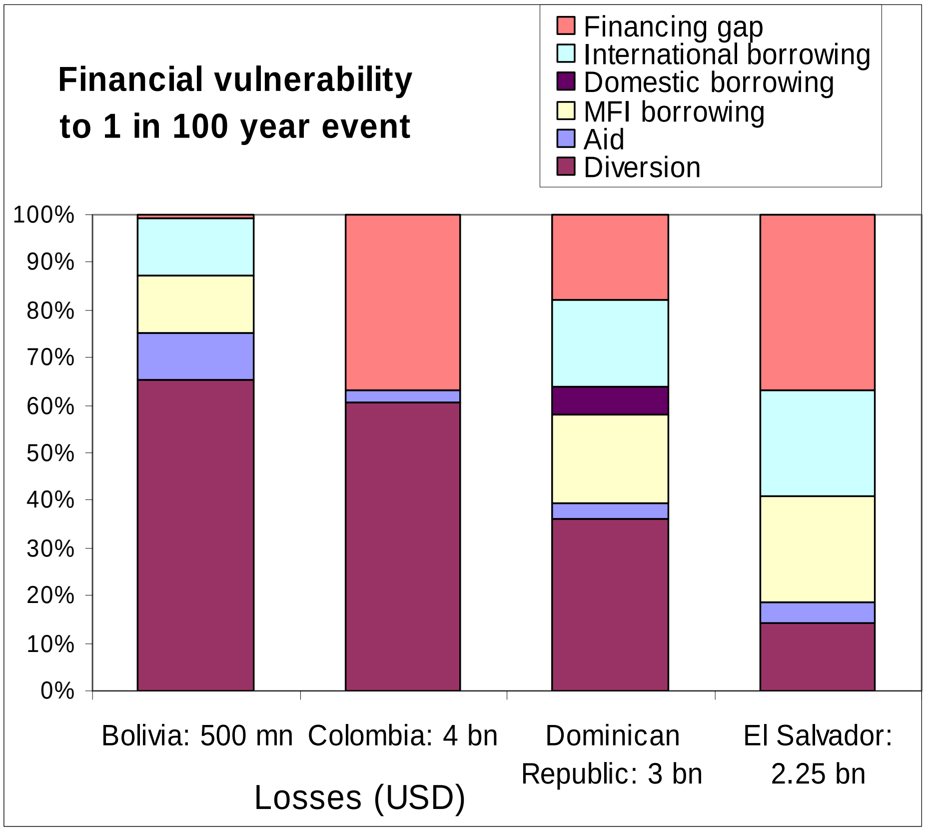


Fig. 3: Financial vulnerability to 100 year event in 4 Latin American countries

Estimates show, for example, that the losses to the Bolivian government due to a 100 year event would have amounted to 500 million USD (from damaged public infrastructure and obligations for relief). If this event had occurred in the 2002 budget period, Bolivia could have financed all but about one percent of its obligations by accessing the following: international and domestic capital markets, support from international financial institutions, international donor aid, and, most importantly, diversions from its domestic budget. Colombia, the Dominican Republic and El Salvador can expect far larger financing gaps mainly because of less slack in their domestic budgets. Because of their lack of resilience and the risks they are facing, in 2002 these governments were highly financially vulnerable to the 100- year disaster event.

Stage 4: Illustrating the developmental consequences of a financing gap

Financial vulnerability can have serious repercussions on the national or regional economy and the population. If the government cannot replace or repair damaged infrastructure, for example, roads and hospitals, nor provide assistance to those in need after a disaster, this will have long-term consequences. The consequences on long-term economic development can be illustrated by the CATSIM tool. For example, figure 4 shows the results of the simulations of growth paths in El Salvador with and without the purchase of insurance for public assets as an ex-ante financial tool.

The figure illustrates the longer-term consequences of these shocks. The economy of this country is expected to grow over time (with the current year as the base year) as investment adds to the capital stock. However, the country can experience disasters, which can be thought of as stochastic shocks to the growth trajectory. CATSIM simulates 5,000 trajectories, although in this Figure only 100 are summarized for illustrative purposes. The trajectories do not have equal probability. The trajectories in the upper part of the figure show economic growth proceeding in the absence of shocks, and these trajectories have a higher probability than the catastrophic cases in the bottom of the figure. Economic growth in El Salvador is higher on average if the government does not allocate its resources to catastrophe insurance (upper figure), but the economy has fewer extremes, that is, it is more stable with public sector insurance (lower figure).

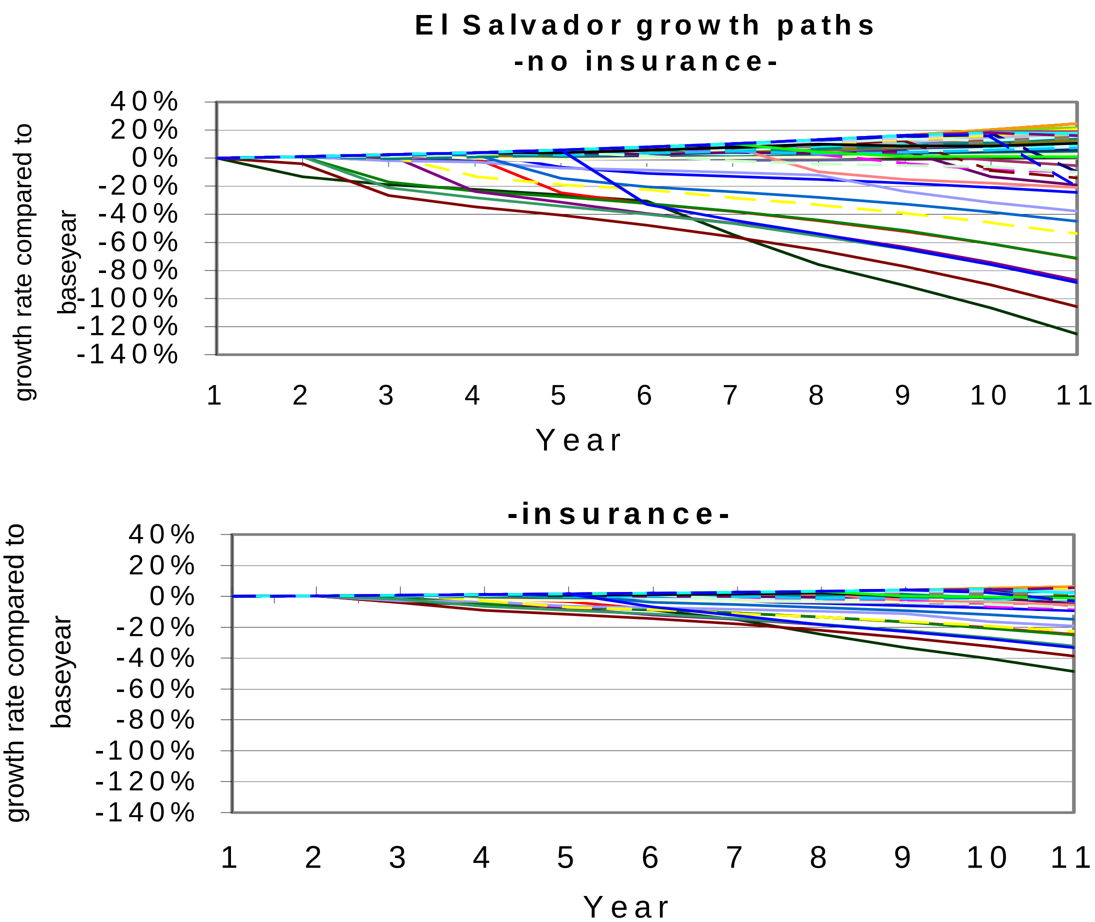


Fig. 4: Simulated Growth vs. Stability for El Salvador over 10-Year Horizon

This growth-stability tradeoff is a difficult one for a developing country like El Salvador, where a large percentage of the population lives in poverty. Ideally, El Salvador could continue on a strong growth path and reduce the possibility of extreme shocks to its economy. Investing in these risk financing instruments can be viewed as a trade-off between economic growth and stability. Budgetary resources allocated to catastrophe reserve funds, insurance and contingent credit (as well as to preventive loss-reduction measures) reduce the potential financing gap, and thus can ensure a more stable development path. On the other hand, ex ante financing and prevention measures come at a price in terms of other investments foregone and thus will inevitably have an adverse impact on the growth path of an economy. The CatSim model assesses this trade-off by comparing the costs of selected ex-ante measures with their benefits in terms of decreasing of the possibility of encountering a financing gap.

Stage 5: Reducing financial vulnerability and building resilience

Vulnerability and resilience must be understood as dynamic. In contrast to ecological systems, social systems can learn, manage and actively influence their situation. There are two types of policy interventions for reducing public sector financial vulnerability: those that reduce the risks of disasters by reducing exposure and sensitivity and those that build financial resilience of the responding agencies. As a relevant case in point, the Colombian government is currently negotiating a loan with the World Bank that would reduce Colombia's natural disaster vulnerability (on average, Colombia has been hit by a disaster once every four years) and improve its physical and financial resilience.

1.3. Beyond indicators: building capacity for Vulnerability reduction

The policy applications of the CATSIM tool can provide insights on the development and use of indicators of vulnerability, resilience coping capacity and other concepts important for policy interventions with regard to disasters and other global-change phenomena. The CATSIM tool relies on quantitative indicators. Risk is estimated making use of historical statistics and exposure; financial resilience is estimated with an index of observations on the financial preparedness of the government; financial vulnerability is a composite of the two and is measured in terms of the financing gap.

Clearly financial vulnerability of the public sector presents only one aspect, albeit an import one, of vulnerability to natural hazards. Other indicators are necessary in order to complement this concept. For example Cardona et al. for the *Information and Indicators Program for Disaster Risk Management* of IADB, ECLAC and IDEA (IDB, 2005) have used the IIASA methodology of financial vulnerability (termed *disaster deficit index* in this context) and complemented this index by other vulnerability indicators such as the *Prevalent Vulnerability Index* accounting for social vulnerability in terms of exposure in hazard-prone areas, socioeconomic fragility and social resilience (Inter-American Development Bank 2005).

Furthermore, participation and transparency in the design, estimation and use of vulnerability indicators is, we would argue, essential for their legitimacy. Yet, participatory, stakeholder forums will likely not reach agreement on the criteria and measures of difficult to measure concepts like risk, vulnerability and resilience. Stakeholders often disagree on the very core of the issues at stake, and have different perceptions of the problem framing and solutions (Linnerooth-Bayer, et al. 2003). Besides participation and transparency, indicators may work best where there is common user agreement on the problem frame and indicator objectives. Quantitative indicators may not thus be suited for forums with contradictory perceptions and views of the issues at hand, but may better serve policy forums of the "like minded". For instance, the U.N. Food and Agriculture Organization (FAO) has developed indicators of potential food scarcity for making decisions on food stockpile locations. There is one clear institutional objective guiding the development and measurement of the indicator, which has been commonly agreed within the organization and successfully applied.

Likewise, CATSIM has been designed for like-minded policymakers intent on reducing the financial vulnerability of the public sector to disasters. This "like- mindedness" does not mean, however, that indicators should be designed, estimated and used in a non-participatory and non-transparent manner. As there is a substantial degree of uncertainty in estimates of disasters risks and financial vulnerability, it is important that users have full participation in their design, estimation and use. CATSIM has been created as a participatory, interactive tool for building capacity of policy makers by sensitizing them to the tradeoffs inherent in planning for disasters. By means of a graphical user interface the user can explore financing issues in the probabilistic context of natural disasters, can change important parameters, and test the sensitivity of outcomes to those changes. In addition, the user is cautioned that the model does not yield "optimal" strategies, but gives insights on the pros and cons of different policy options.

The model underlying CATSIM was originally developed for the Regional Policy Dialogue of the Inter-American Development Bank, where it was applied to Latin American case studies (Freeman et al. 2002b). Based on this model, the CATSIM simulation tool was designed and successfully employed for informing economists, financial experts and policy makers in stakeholder workshops, who are interested in taking account of disaster risk in public finance theory and practice on the financial management of disaster risk.

2. CatSim Introduction

The CatSim (Catastrophe Simulation) Model is designed to illustrate the tradeoffs and choices a country must make in managing the economic risks due to natural disasters. Budgetary resources allocated to ex-ante disaster risk management strategies, including loss mitigation measures, excess of loss insurance, reserve fund and contingent credit arrangements for public assets, reduce the probability of financing/resource gaps - the inability of governments to meet their full obligations in providing relief to private victims and restoring public infrastructure – or prevent the deterioration of the ability to undertake additional borrowing without incurring a debt crisis. Figure 5 shows the risk management approach of CatSim:

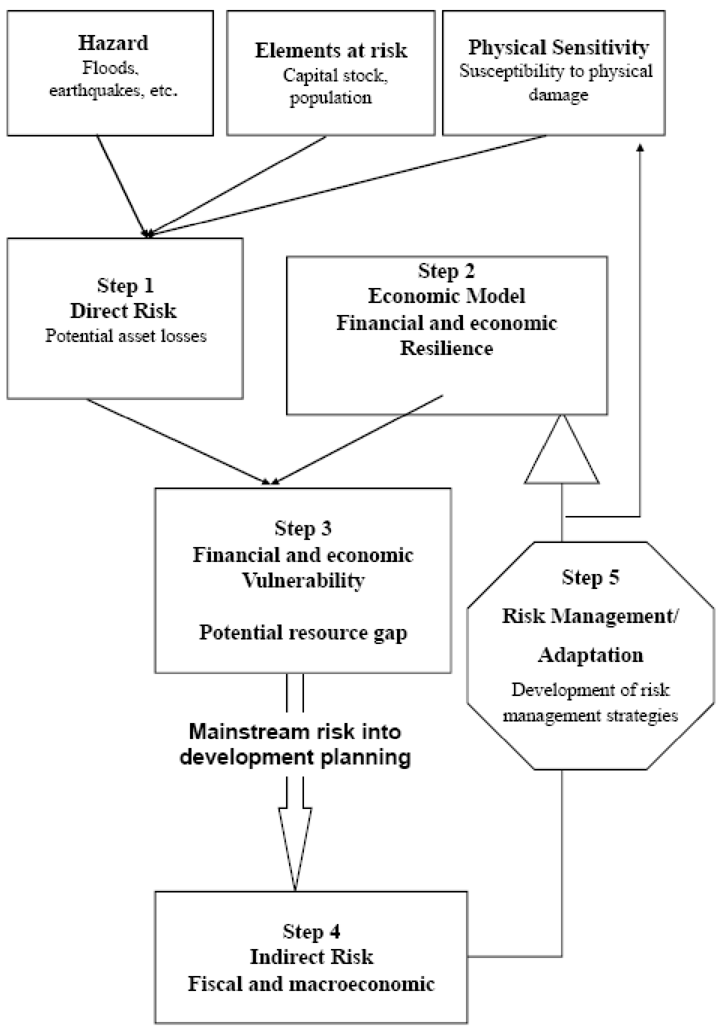


Fig. 5: The CatSim (Catastrophe Simulation) approach.

Hazard, exposure and physical sensitivity are determining the direct risk of potential asset losses by the use of loss distributions, also represented as exceedance probability loss curves. Financial vulnerability is measured through the resource (also called financing) gap concept and describes the ability of the public sector to finance reconstruction of lost stocks and provide assistance to the business sector (as an insurer of last resort) and households. The financial vulnerability is determined by the direct risk and the financial resilience of the government, which also determines their macroeconomic risk (e.g. indebtedness, growth and growth stability) of negative long term impacts in the future (e.g. 10 years). Due to risk management options, the financial resilience can be strengthened which as a consequence lessens the financial vulnerability and therefore macroeconomic risk. The user interfaces guide the user through each step of the above figure, which are explained in more detail below:

- **Step 1: Assessment of risks to public sector assets**
  In developing a risk management strategy, it is important to understand the financial risks of asset losses and relief expenditure to assist households and business, and the proportion of financial losses that will be absorbed by the government. This risk depends on the frequency and intensity of the hazard event (e.g. cyclones), the assets exposed to the natural phenomena and their physical vulnerability.

- **Step 2: Estimation of the financial resilience of the public sector**
  Given limited resources for reducing human and economic losses, the government must be financially resilient, or provide sufficient funds for financing reconstruction of public infrastructure and the provision of relief to households and the private sector. Financial resilience will, in turn, depend on how much the risk is reduced thus affecting the general economic conditions of the country.

- **Step 3: Assessment of the "resource gap"**
  The resource gap is the difference between the contingent post-disaster liabilities of the government (for repairing infrastructure and providing relief to the private sector) and the sources of funding available to the government. It can be assessed by simulating the risks to public assets and estimating the government's ability to cover these risks as well as provide private sector assistance.

- **Step 4: Mainstreaming disaster risk into development planning.**
  Disaster risk is mainstreamed into national development planning by incorporating financial disaster risk and potential resource gaps for funding these losses into macroeconomic projections of the country. These consequences can be analyzed on variables such as economic growth or the country's external debt situation. These indicators represent impacts on economic flows as compared to impacts on stocks addressed by the financial asset risk estimation.

Risk management: evaluating pro-active strategies

- **Step 5: Assessment of government programs to reduce risks**
  Naturally, the government is concerned primarily about loss of life from disaster events (e.g. cyclones), and also about loss of livelihood and productive assets. As an important step in any risk management plan, it should consider the cost effectiveness of government programs to reduce human and economic losses.

- **Step 6: Assessment of pre-disaster insurance and other risk financing options**
  There are several options the government can consider in proactively reducing its risk of a resource gap, including insurance, using catastrophe bonds, a reserve fund or contingent credit arrangements. It is important to examine the cost effectiveness of these instruments in reducing the resource gap risk.

In CatSim, strategies can be developed and illustrated that reduce the risks of disasters and build the financial resilience of the public sector. The development of risk financing strategies has to be understood as an adaptive process, where measures are continuously revised after their impact on reducing financial vulnerability and risk has been assessed.

Generally speaking, in CatSim the problem of disaster risk management for developing countries is approached as a two stage decision problem under uncertainty. The first stage is the ex-ante stage, where budget allocation can be made to undertake mitigation measures, buy insurance or other financial protection instruments for public assets. The second stage is the ex-post stage, the decision stage after a disaster, where repair, budget reallocation and other financial decisions (tax increase, loans etc.) are made. The problem is treated in a integrative fashion: The scope of possible actions at stage two influences the decision at stage one. Monte-Carlo-Simulation approaches are used to generate the scenarios for a given time horizon, e.g. for a time horizon of 10 years, more than 3200 scenarios for losses caused by catastrophic events within the time period are generated.

In the following the user interfaces, some guidelines for the use of CatSim, important variables and their presentation within CatSim are shown. Finally, a illustrative example is given.

3. CatSim Parameters

There are basically two CatSim windows where the input data is defined: The "Direct Risk" window as well as the "Financial Resilience" window. All windows for CatSim are described in detail in the next chapter. Here, we will give the full list as well as the definitions of all the parameters used. The abbreviations of the parameters are the same as in the model. The first input window is the "Direct Risk" Window.

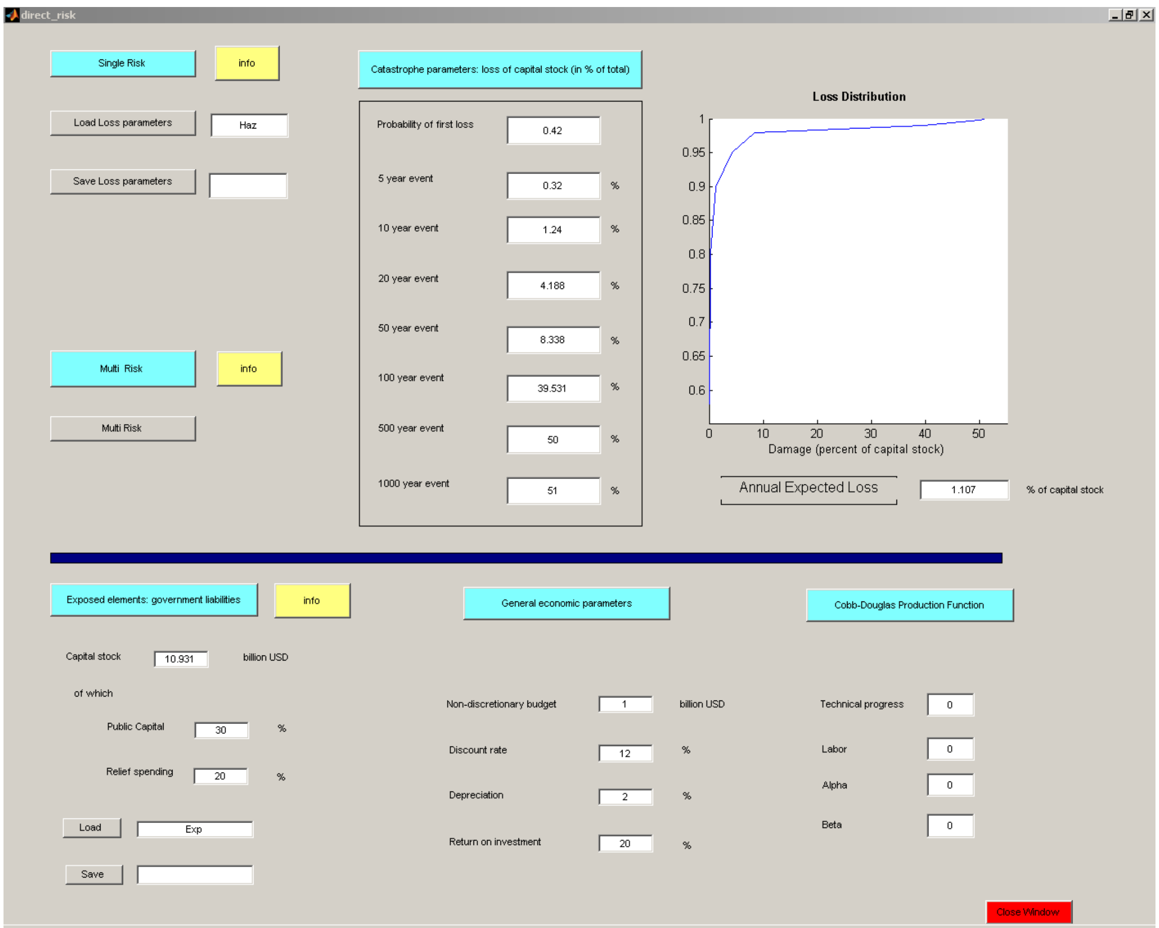


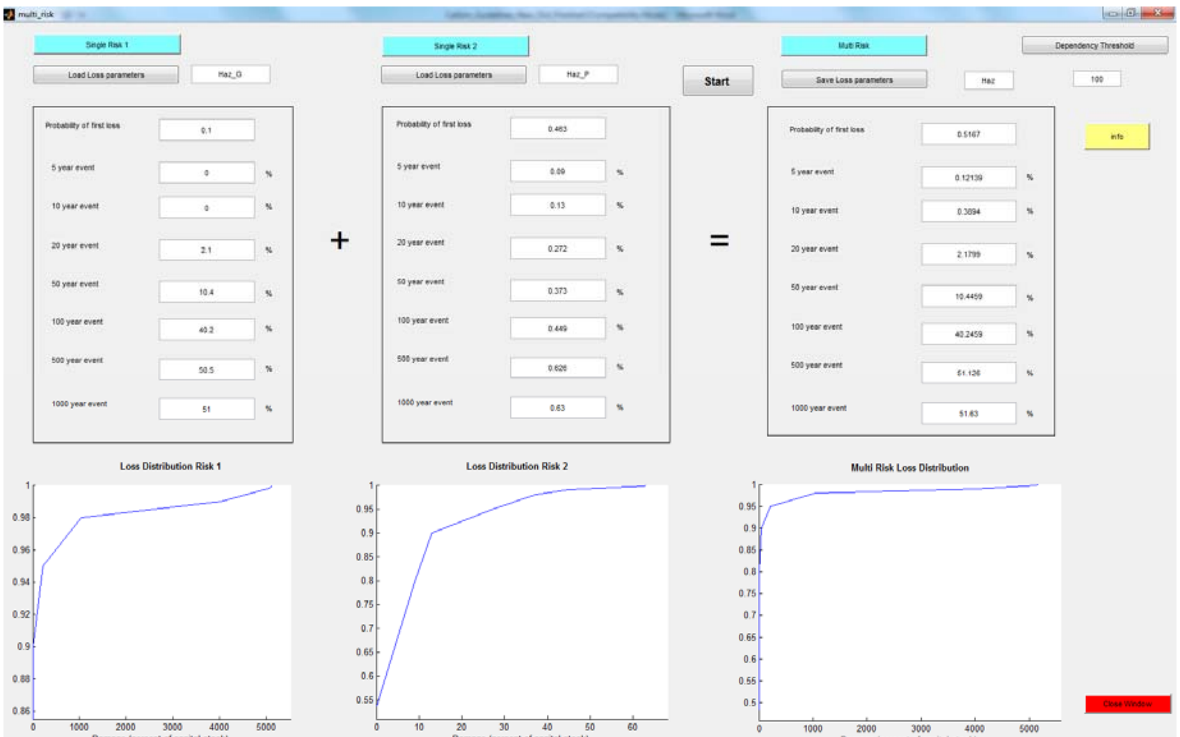
Fig. 6: Direct risk window

The direct risk window defines the risk the country is exposed to. It is the outcome of Step 1. If the "Load Loss Parameters" button is pushed then the baseline values (see Madagascar report) are loaded. The following parameters are defined here.

Hazard and Loss Parameters	**Explanation**
Probability of First Loss	- The probability that in a given year a loss due to cyclone events will occur. - A number between 0 and 1. - Example: If it is 0.4, than it means that with 40 percent probability a loss will happen this year. In other words, with 60 percent probability no losses will occur. - This number is derived from the loss estimation procedure (see Madagascar risk report). - Given a loss event happens, the next variables give information about the level of losses
5 year event	- Percentage of losses (in percentage of capital stock destroyed) if a loss event with a 5 year return period will occur. - Such an event will occur on average every 5 years or with probability of 20 percent annually (each year). - Mathematically, it is defined as the 80 percent probability that losses are below a given level (defined in the relevant box), i.e. P(X<=x)=0.80. - The other variables are defined similarly. - Note: The higher the return period the lower the probability of occurring. The lower the occurrence probability the higher the losses. - The numbers are derived from the loss estimation procedure (see Madagascar risk report).
10 year event	- Percentage of capital stock destroyed in the 10 year event. P(X<=x)=0.9
20 year event	- Percentage of capital stock destroyed in the 20 year event. P(X<=x)=0.95
50 year event	- Percentage of capital stock destroyed in the 50 year event. P(X<=x)=0.98
100 year event	- Percentage of capital stock destroyed in the 100 year event. P(X<=x)=0.99
500 year event	- Percentage of capital stock destroyed in the 500 year event. P(X<=x)=0.998
1000 year event	- Percentage of capital stock destroyed in the 1000 year event. P(X<=x)=0.999

With these numbers a loss distribution on the right hand side of the window is shown too. Furthermore, the expected annual losses are calculated. These are the losses (in percent of capital stock destroyed) one can expect to happen each year on average. It is calculated as the area above the loss distribution.

If more than one hazard is looked at one can click at the multi-hazard button and an additional window appears where both loss distributions can be summed using a hybrid-convolution technique (for more details see Hochrainer et al. 2014 and the Madgascar report).



In the figure above two loss distributions defined in terms of loss return periods are used as the input parameters and after defining the threshold level on the upper right hand side of the window (which defines at what return period a full dependence between the losses is assumed and below this value full independence is assumed) pushing the Start button will give the loss return periods for the combined hazard risk which can serve as input parameters for the direct risk window (Figure 6).

Exposure Parameters	Explanation
Capital Stock	- Total capital stock at risk in billion USD. - This includes all assets which are exposed to cyclones from the private as well as public sector. - Public sector assets include for example, infrastructure, schools, hospitals, etc. - Private sector assets include households, houses, business etc. - Estimated here by using a GDP and capital stock relationship from Sanderson et al. 2009 (see Madagascar risk report) - Has to be updated if new data is available
Public	- Capital stock is total capital stock from the private and public sector. This variable determines the percentage of the total capital stock belongs to the public sector responsibility - Estimated here using loss reports and literature reviews (see Madagascar risk report)
Relief	- The percentage of the private sector losses the government will compensate, e.g. for helping the poor. - A percentage of 20 percent means that 20 percent of the total losses which belong to the private sector will be financed by the government - Estimated here using loss reports and literature reviews (see Madagascar risk report) - Has to be updated according to policy options.
Non-discretionary budget	- The budget which is needed to provide basic operations of the public sector (in billion USD) - It is the minimum amount the government needs to spent to keep everything running. It cannot be used for something else, e.g. risk management
Discount rate	- The discount rate is used to discount future expenditure and growth to current prices. See Net present value.
Depreciation rate	- The depreciation rate is used to depreciate the value of assets for future time periods.
Return on investment	- The percentage of how much the government will receive return if it invests in public sector assets. - Has to be updated according to finance ministry projections.

A Cobb-Douglas production function is used for estimating future macroeconomic performance. The following **exogenous growth model** is used.

- Supply: Cobb-Douglas $Y^S = A\,K^a\,L^b$
- Demand side: $Y^d = C+I+G+X-M = C+S+T$
- Investment: $I=S=sY$
- Capital accumulation: $DK = sY - DK_{dep} - DK_{Cat} + I_{recon}$
    - DK_{Cat}: stochastic disaster shock to K, random Monte Carlo draw from distribution
    - I_{recon}
        - Algorithm for finding additional savings for reconstruction to continue growth
        - Based on resource gap concept: lack of financial resources for achieving growth targets (Chenery and Strout 1966)
- Caveats: no learning or technological progress

Here, A is the technological growth parameter, K is the capital stock and L is the labor. Alpha and beta are the parameters a and b. They are estimated as discussed in the Madagascar risk report. The second input window is the “Resilience” Window (see below).

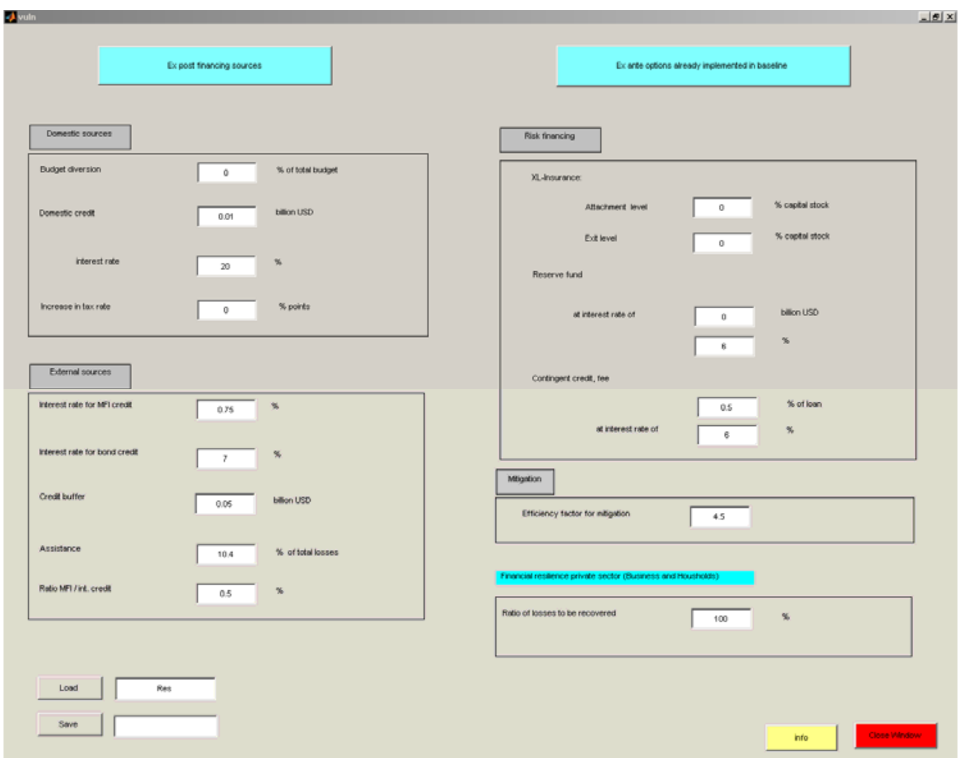


Fig. 7: Resilience window

Resilience Parameters	**Explanation**
Budget diversion	- The percentage of the discretionary budget which can be diverted for loss operations. - Example: if budget diversion is set as 10 percent and total budget is 2 bn USD and 1.5 bn USD is non-discretionary budget, than 50 million USD could be used (maximum) for loss financing. - Numbers should always be checked within the Financing Gap analysis windows (see next chapters).
Domestic Credit	- The amount of money (in bn USD) the government could take from domestic banks and or/print money without causing any inflationary situations.
Increase in Tax rate	- Increase in tax rates in percentage points - Numbers should always be checked within the Financing Gap analysis windows (see next chapters).
Credit buffer	- The total amount (in bn USD) the government could borrow from international banks or multilateral financing institutions (e.g. World Bank). - is defined as 150% of the typical export value of this country minus the present value of existing loans (HIPC, 2002). - See Madagascar risk report - Has to be updated annually
Assistance	- Monetary help from outside assistance in percentage of total losses.
ratioMFI/int.Credit	- MFI and international credits are assumed to have different interest rates to pay back the loan - The ratio determines how much credit can be taken from MFIs and how much from international credits. - Irrespective of the number, not more than the credit buffer can be taken from these institutions.
Ratio of losses to be recovered	- How much of the private sector losses can be financed by the private sector entities without any significant future stress on its economic performance - A value of 100 means that all losses the private sector is responsible for, can be financed
Efficiency factor for mitigation	- This number tells how many dollars could be saved if one dollar is spent for mitigation. - Based on literature review. 4.5 means that 4.5 dollars of losses could be prevented if 1 dollar is spent for mitigation. - Up to now a generic option. Has to be updated according to the specific mitigation option in place.

	- See Madagascar risk report for more information
Reserve Fund	- Amount of money (in bn USD) used for a reserve fund and interest rate. - It is assumed to be a cumulative fund, i.e. each year the same amount of money will be put into the fund. - See Madagascar risk report for more information
XL Insurance	- Excess of loss insurance. - Insurance starts (attachment level) at a given percentage of capital stock destroyed and ends (exit level) at a given percentage of capital stock destroyed. - See Madagascar risk report for more information
Contingent credit	- Percentage of annual payments in terms of maximum loan amount possible. - Is based on the economic performance of the country. - Numbers should always be checked within the Financing Gap analysis windows (see next chapters).

4. User Interfaces

In this section, each of the user interfaces in the standalone application of CatSim is shown and described in detail.

4.1. Main Menu

After starting CatSim (double click on catsim.exe) the main menu appears (Figure 8). In the main menu one can chose between two sorts of analysis: Vulnerability and Risk Assessment and Financial Risk Management Analysis. While the former one performs a risk analysis for the next year (Step 3 of the CatSim approach), the later one uses probability based approaches for longer time horizons (Step 4 and 5 of CatSim).

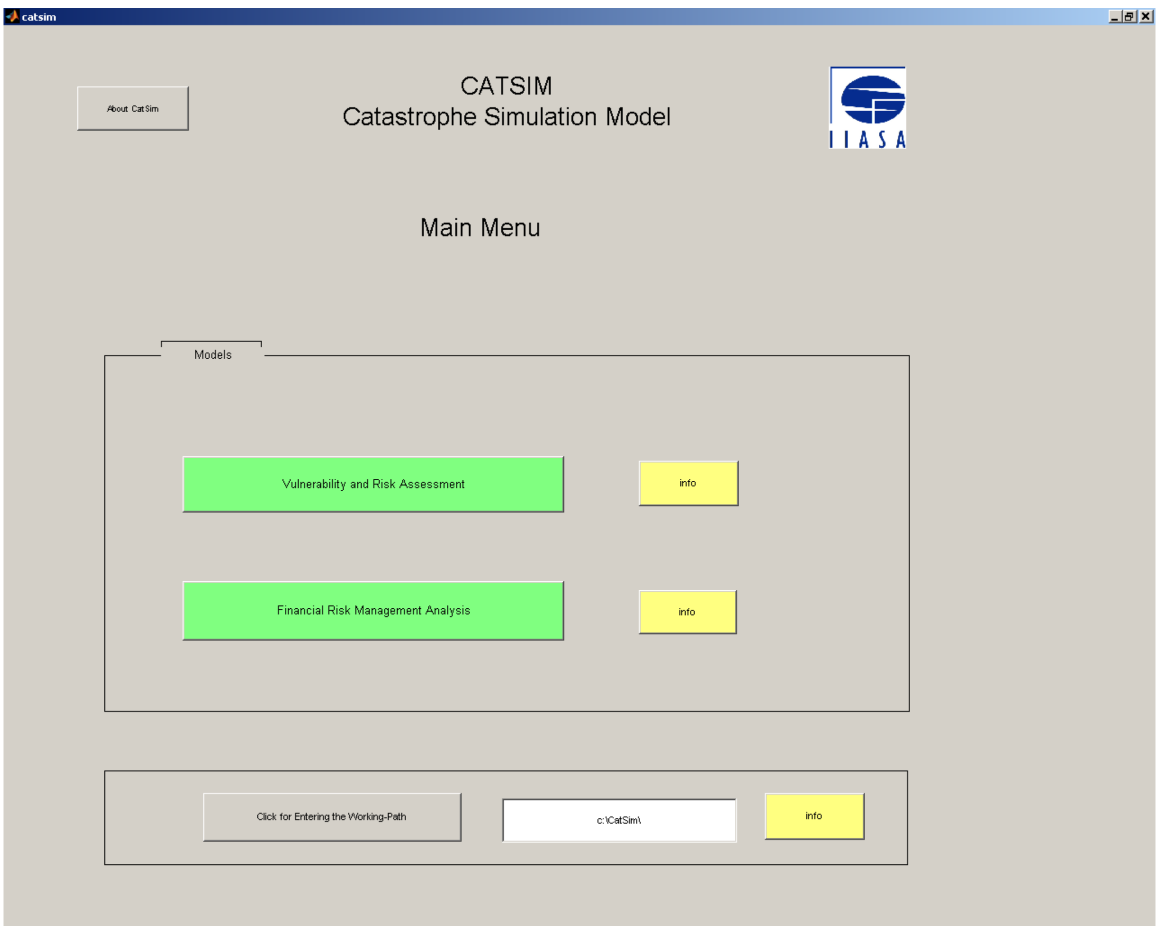


Fig. 8: Main Menu

At the bottom of the menu there is also the directory path where the files will be saved and loaded from. Usually, the directory should be the work directory where CatSim is installed, e.g. c:\catsim\. This directory can be changed by writing a new directory in the text window in the main menu and pushing the button on the lower left hand side afterwards (the directory c:\catsim\ will be used as the standard work directory in this document). Double clicking at the top edge of the user interface windows will increase the window size to its maximum size.

Note, there are usually yellow boxes in the relevant places on each user interface which (by clicking on it) will give detailed information of the specific variable and/or approach used.

4.2. Vulnerability and Risk Assessment

The following window (Figure 9) appears if you push in the main menu (Figure 8) on the 'Vulnerability and Risk Assessment' button.

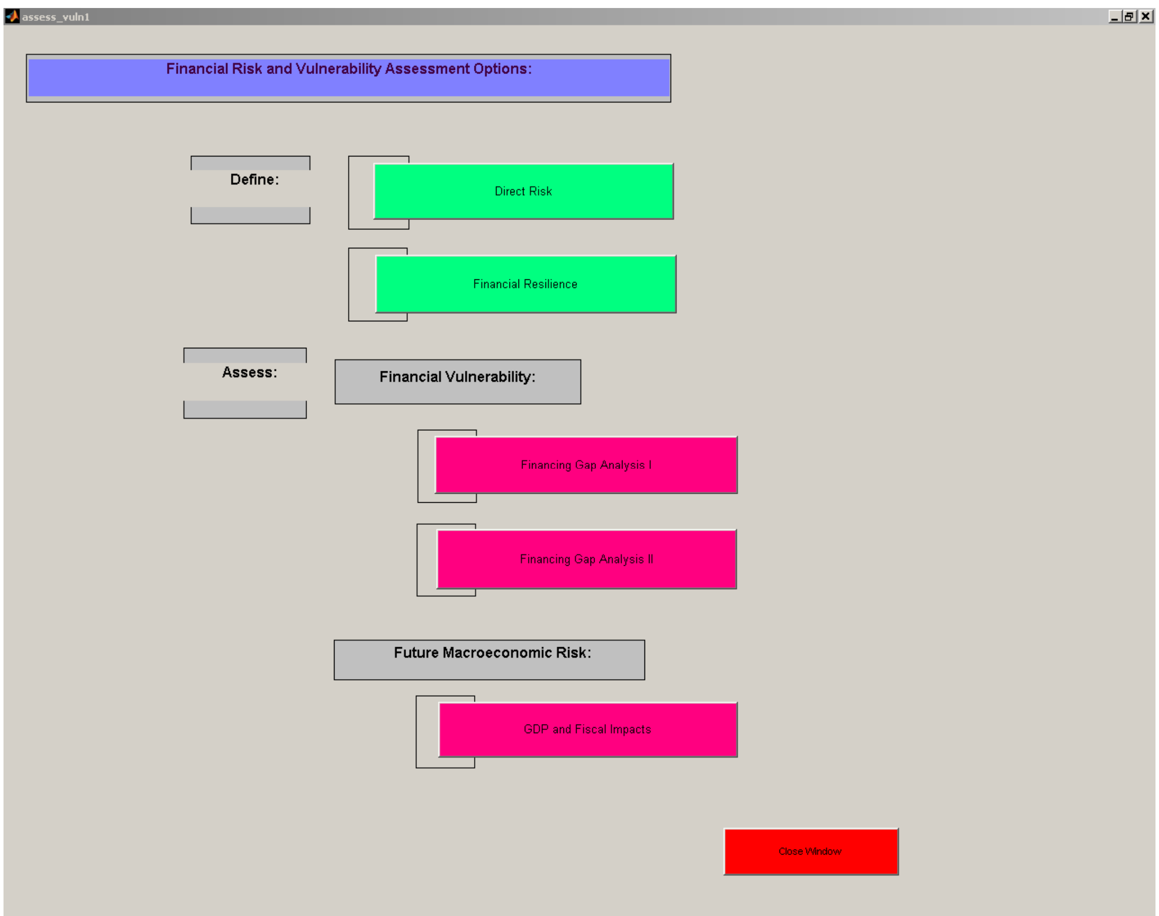


Fig. 9: Financial vulnerability and risk assessment menu

Usually one starts with defining the direct risk the country is exposed to. This is the first button at the top. It combines the information about the hazard, the physical sensitivity and the elements at risk via a loss distribution. The second button defines the financial resilience of the government. After defining these elements in the relevant user interfaces, financial vulnerability via the resource gap concept can be analyzed and long term consequences calculated. Next, we proceed by explaining the “direct risk” window.

4.2.1. Direct Risk:

The following window (Figure 10) appears if you push the direct risk button in Figure 9.

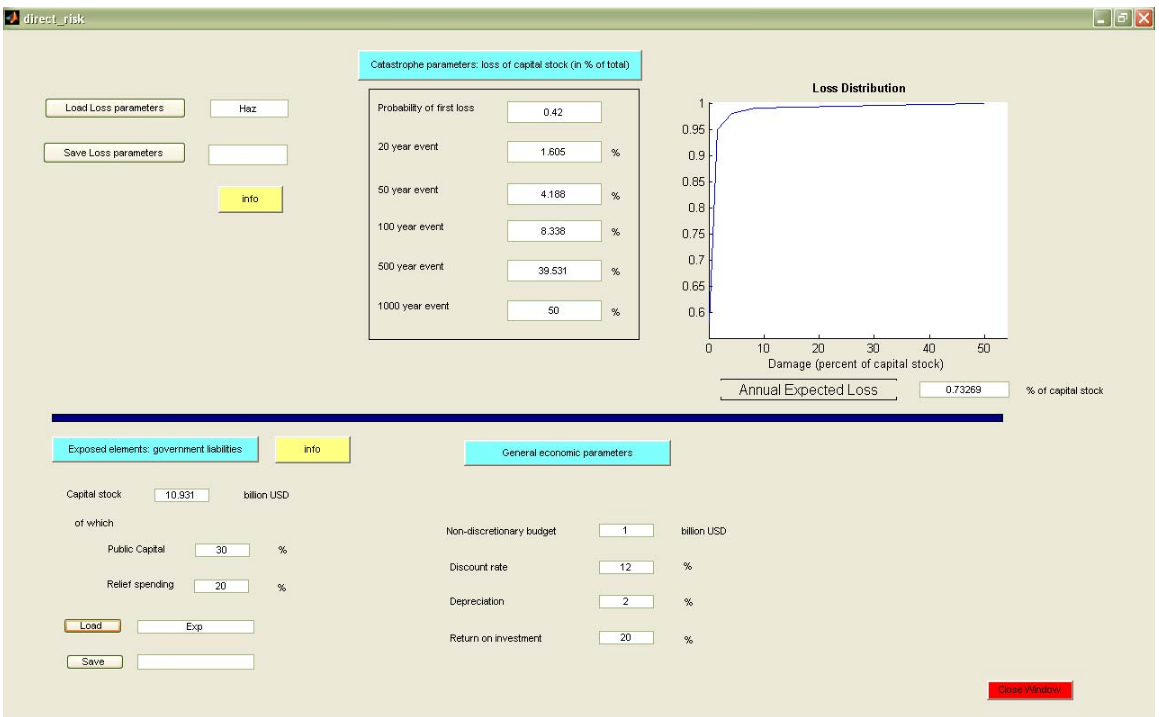


Fig. 10:   Direct risk window

To load up a file, type in the file name (e.g. Haz) in the upper left corner and push the “Load Loss parameter**s”** button. The following numbers are loaded from the file,

- Probability of first loss: Is defined as the annual probability that losses will occur. For example, a value of 0.50 means that each year with 50 percent probability an event will cause losses. Given a loss event happens, the next variables give information about the level of losses (see loss distribution and exceedance distribution concepts in Hochrainer 2006)

- Percentage of capital stock destroyed in the 20 year event. This is defined as the 95 percent probability that losses are below a given level (defined in the relevant box), i.e. P(X<=x)=0.95. The other variables are defined similarly.
- Percentage of capital stock destroyed in the 50 year event. P(X<=x)=0.98
- Percentage of capital stock destroyed in the 100 year event. P(X<=x)=0.99
- Percentage of capital stock destroyed in the 500 year event. P(X<=x)=0.998
- Percentage of capital stock destroyed in the 1000 year event. P(X<=x)=0.999

One can also change the parameters and save the changes afterwards. To do that, just change the relevant variables and type in a new file name. Afterwards push the “Save Loss parameters” button. The file is then saved under the file-name in the directory you have selected in the main menu (Figure 8).

If you do not have any loading file yet, just write in the parameters by hand and save the file, you then have a file in the correct order to be used afterwards for loading and changing parameters in the risk analysis section.

The window also shows the loss distribution (Hochrainer 2006) where the x-axis shows the percentage of capital stock destroyed for the different year events and below the annual expected loss (losses you can expect annually) is shown.

Under the blue line there are also some other parameters you have to define to describe the direct risk (and some economic variables needed for the macroeconomic model) in more detail. On the lower left corner you can again load (e.g. Exp) and save the parameter settings (called the exposure file here). The parameters include the total capital stock at risk in bn. USD dollar terms, the percentage of the losses which the government is responsible (separated into percentage of public and private) and some economic parameters, defined next:

- Non-discretionary budget means the minimum amount of budget the government needs each year for basic services (salaries etc.).
- The discount rate is needed to calculate the Net present value of future capital stock, credits etc.
- The depreciation rate defines the depreciation of capital stock over time.
- Return on investment gives the percentage of return (e.g. in form of taxes) due to the capital stock it has owned (i.e. public capital).

4.2.2. Financial Resilience

Pushing the Financial Resilience button in Figure 9 opens the financial resilience window (Figure 11). Saving and loading files (e.g. Res) is done in the same manner as in the direct risk window (Figure 10). For example, to save a file (called the resilience file, Res), type in the file name and press the save button. If you do not have any loading file yet, just put in the parameters by hand and save the file, you then have a file in the correct format and you can use it afterwards for loading and changing parameters.

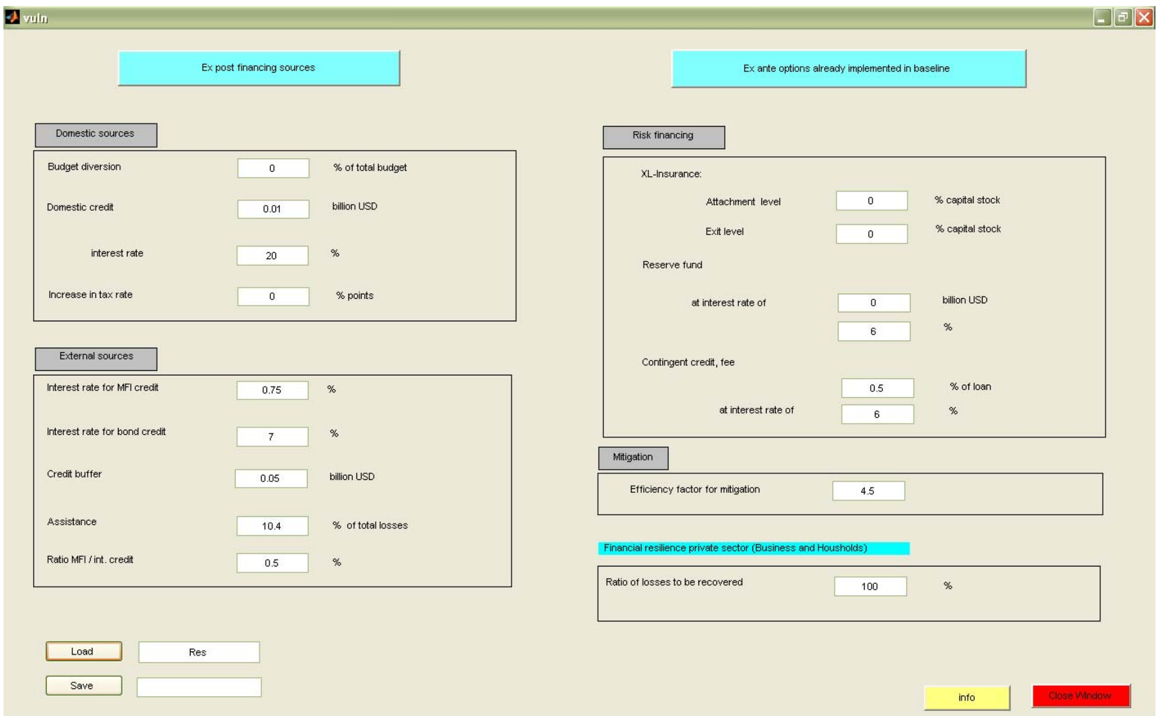


Fig. 11: Financial resilience window

The following variables in this window have to be defined.

- Diversion from budget: The percentage of budget which could be diverted from the total budget to finance the losses.
- Domestic credit: The maximum amount of domestic credit (in bn. USD) the government could take. Also the interest rate for this credit has to be specified.
- Increase in tax rate: Increase in tax rate which is solely used for financing the losses.
- Interest rates for MFI and bond credits have to be specified in the external sources section.
- The credit buffer is the maximum amount (in bn. USD) the government can take from international bonds as well as MFI credit arrangements.

- Assistance is measured in percentage of total losses. Usually it is around 10.4 percent but can be changed accordingly.
- The ratio MFI to int. credit determines how much of credits can be taken from MFI and how much can be taken from financial markets.
- The attachment level and the exit level of a XL insurance arrangement is here determined in percentage of capital stock.
- The reserve fund starting level (in bn. USD) and the interest rate for this fund have to be specified in the risk financing section.
- The contingent credit fee is dependent on the amount of loan which is taken. Furthermore, the interest rate for such a credit has to be specified
- The efficiency factor for mitigation is defined as the amount of money saved by investing one USD, e.g. a value of 4.5 means that if one dollar is spent for mitigation, losses will be lower by 4.5 USD.
- Also the financial resilience of the private sector can be determined by specifying how much of the private sector losses can be financed without any long term consequences.

4.2.3. Financing gap analysis I

Pushing the Financial gap analysis button in Figure 9 opens the financial resilience window (Figure 12).

Here you can look at the loss financing schemes till the critical year event (the year event when for the first time a financing gap would start). Again the files have to be loaded first (e.g. Haz, Exp, Res). Afterwards, it is possible to change the ordering of the ex-post measures which are used first, second, etc. in the loss financing process and compare the results in the figures after pushing button “Optim_Calc”.

The upper figure shows on the x- axes the year events and on the y-axes the loss financing schemes. One then can change the ex-post ordering on the left hand side and /or the variables on the top again and by pushing the “Optim_Calc” button the new results are shown. The critical year event is shown on the lower left hand side of the figure.

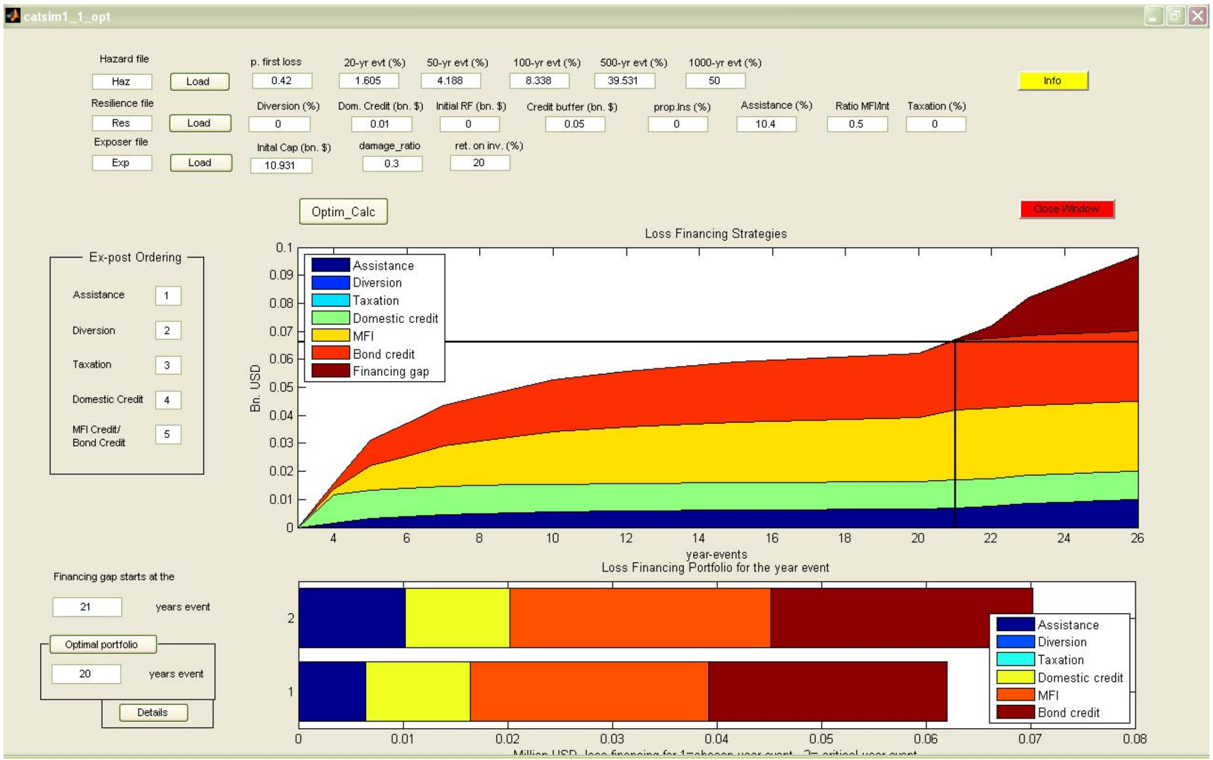


Fig. 12: Financing gap analysis I window

Further analysis can be performed by comparing the loss financing strategies for a specific year event with the loss financing in the case of the critical year event by selecting a year event (e.g. “20” for 20 year event) in the lower left hand cell and pushing the “optimal portfolio” button. For a detailed list of the resources used one can also push afterwards the “Details” button in the lower left hand side. A new window appears (see Figure 13). Pushing in this figure the “Show numerical results” will show the losses the government is responsible for and also the loss financing resources it uses to finance them for the selected event. Note, the year event in the optimal portfolio box must be smaller than the financing gap year event. The maximum amount of financing resources are shown in the second graph, the first bar.

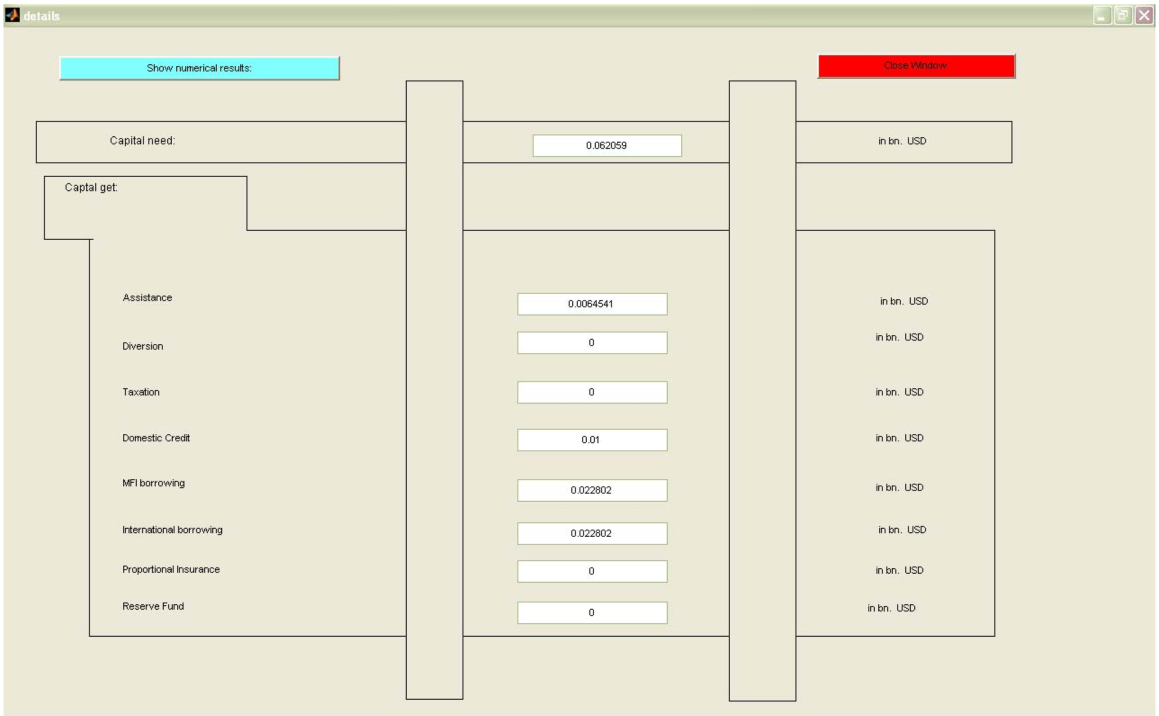


Fig. 13: Detailed loss financing information for specific loss year event.

Afterwards you can close the window and push the button financing gap analysis II Figure 9.

4.2.4. Financing gap analysis II

Again you have to load your files first, by typing in the file names (e.g. Haz, Res, Exp) and pushing afterwards the load button. Then you can push the ‘Gen Ex-post’ button and the results are shown after some seconds (Figure 14).

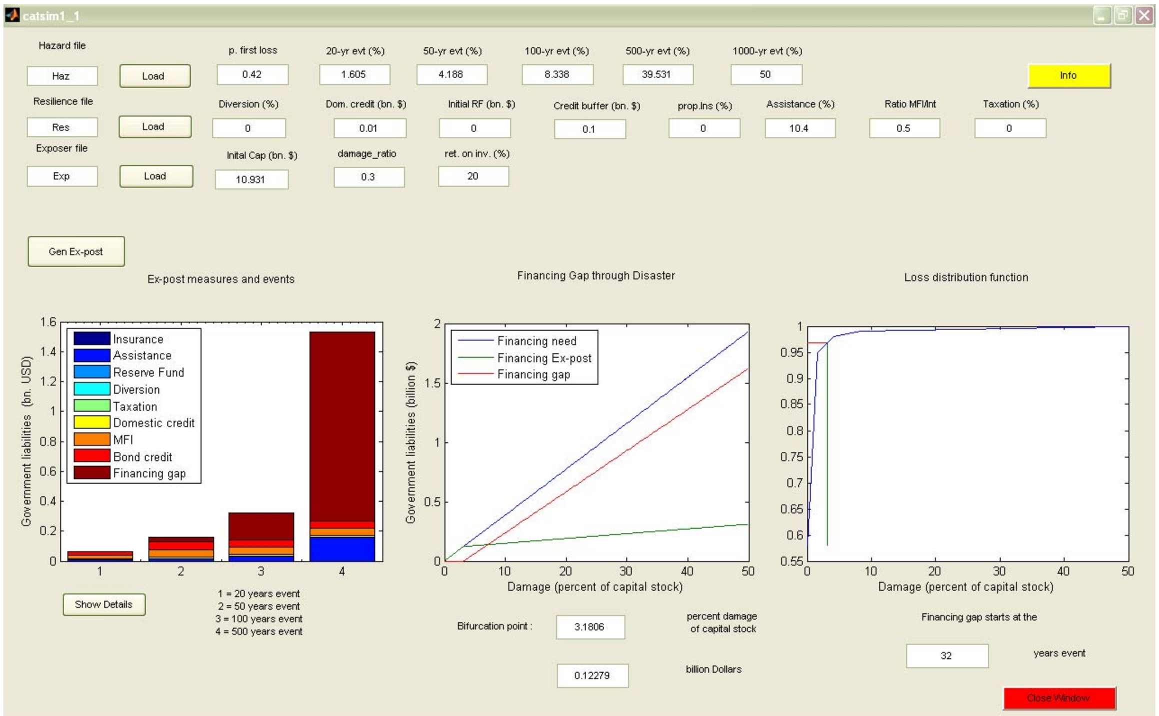


Fig. 14: Financing gap analysis II window

In more detail, on the upper left corner three file names defining the hazard (loss distribution in relative terms), the financial resilience and elements at risk (in dollar terms) are entered and loaded by pushing the load buttons. Afterwards, by clicking the “Gen Ex-post” button various types of analysis are performed. On the left hand side 4 loss year events (the 20, the 50, the 100 and the 500 loss year event) and the loss financing of the damages are presented. For a closer look one can also push the Show details button and Figure 15 opens which show details about the financing schemes used to finance all or (in case of a resource gap) part of the losses.

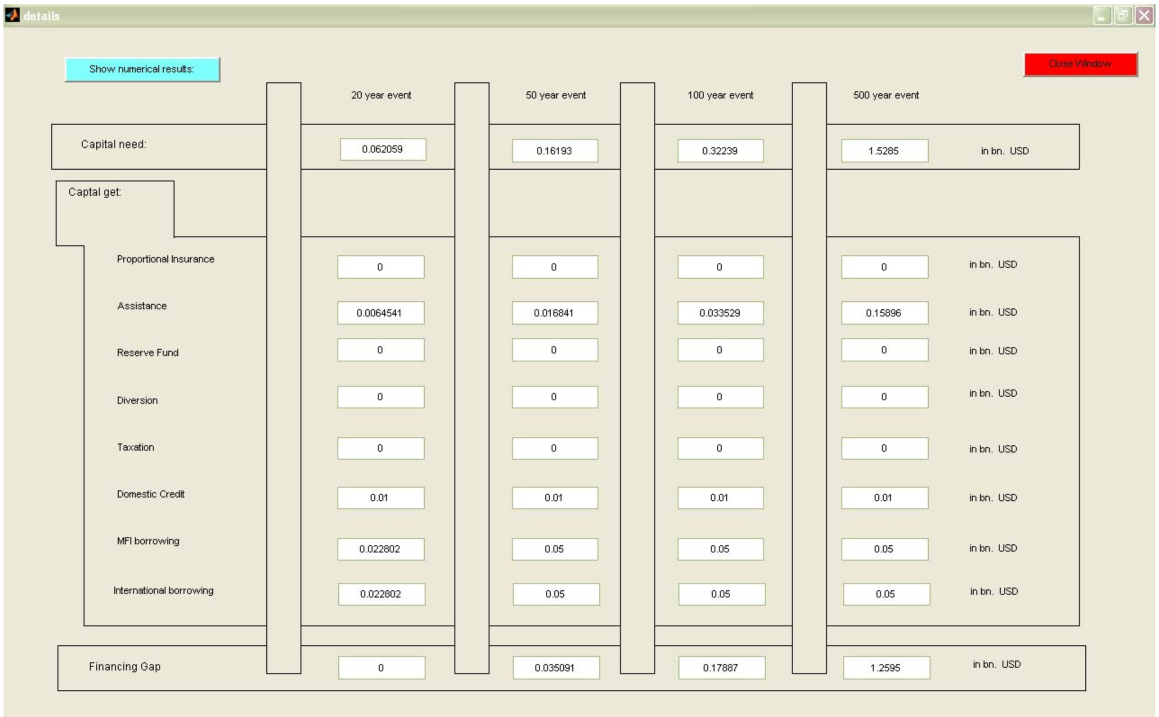


Fig. 15: Details of the 20, 50, 100 and 500 loss year events and financing schemes.

The middle plot in Figure 14 (and the lower two numbers which can found) show the bifurcation point were the losses exceed the capability of the government to finance them. The figure on the right hand side shows again (as in Figure 10) the loss distribution function and the maximum loss amount the government is capable to finance, which translates into the critical year event (i.e. the year event where for the first time a financing gap occurs) which is shown below.

After these financial vulnerability analysis (Step 3 of the CatSim approach) one can close the windows (e.g. 6,7,8, and 9) and push the ‘GDP and fiscal impacts’ button in Figure 9. While until now the current financial vulnerability was analyzed in the following the future vulnerability and risk (e.g. over a 10 year time period) is investigated

4.2.5. GDP and Fiscal Impacts

Figure 16 will be shown. Again you have to load the files by typing in the names of the file and afterwards pushing the load button. Then one can chose the time horizon of interest (10 years as the standard case) and afterwards one can look at the different trajectories (or future paths) of various variables, including GDP and discretionary budget as well as the relation between the discretionary budget and revenue.

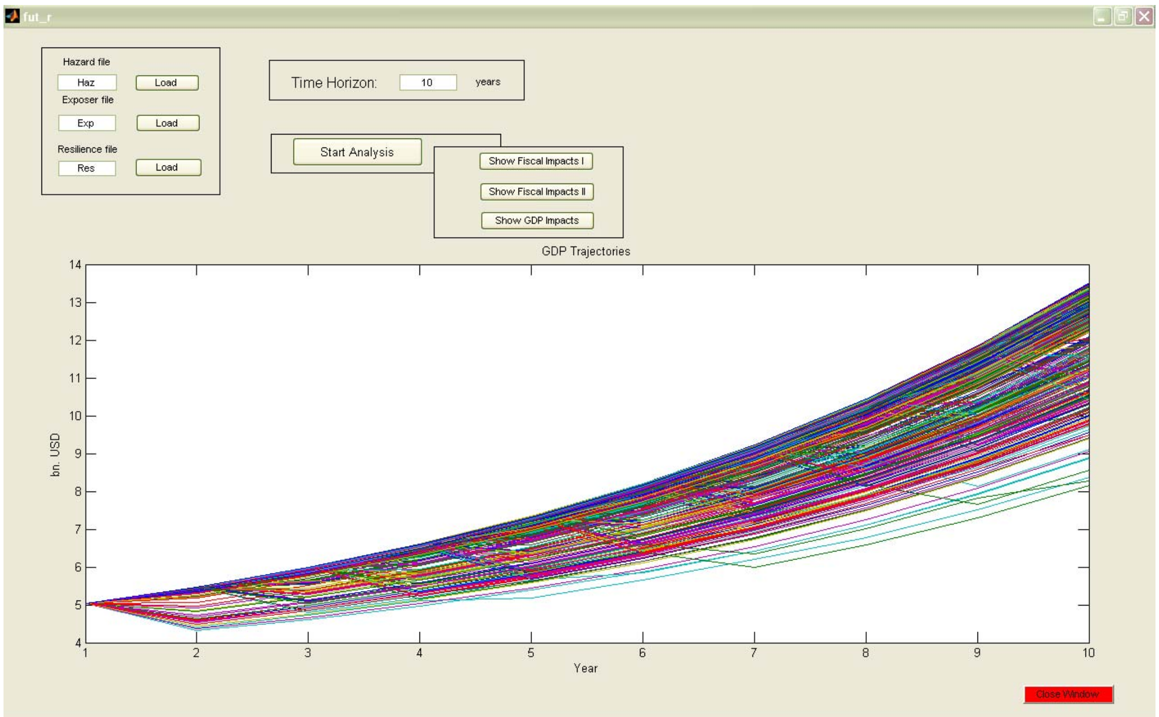


Fig. 16: Future GDP paths with catastrophe risk incorporated.

After this analysis, the financial vulnerability and risk analysis is done and one can close Figure 9 and go into the risk management model via pushing the 'Financial Risk Management Analysis' button in Figure 8.

4.3. Financial Risk Management Analysis:

The following window (Figure 17) appears afterwards. Again the files for the hazard, resilience and exposure are loaded by typing in the file name on the upper right hand side and pushing the load button. Various variables can be changed by typing in different numbers in the upper middle area of the window and by pushing the "Confirm variables" button afterwards. Furthermore it is also possible to change the time horizon on the right hand side, the other variables there are for the stochastic trajectory estimations, scen 1 defines the number of samples for each type of impact in the one event scenario case, while scen 2 defines the number of samples for the two event scenario case, step defines the increasing steps of using part of the discretionary budget for the different instruments, dstep2 defines it specifically for the insurance instrument. By pushing the confirm variables button, the variables are saved for the analysis and trajectories for the time horizon are computed (usually a few thousands); they are needed for the simulation. Only after these changes and simulations are saved/done one should push the Start sim button.

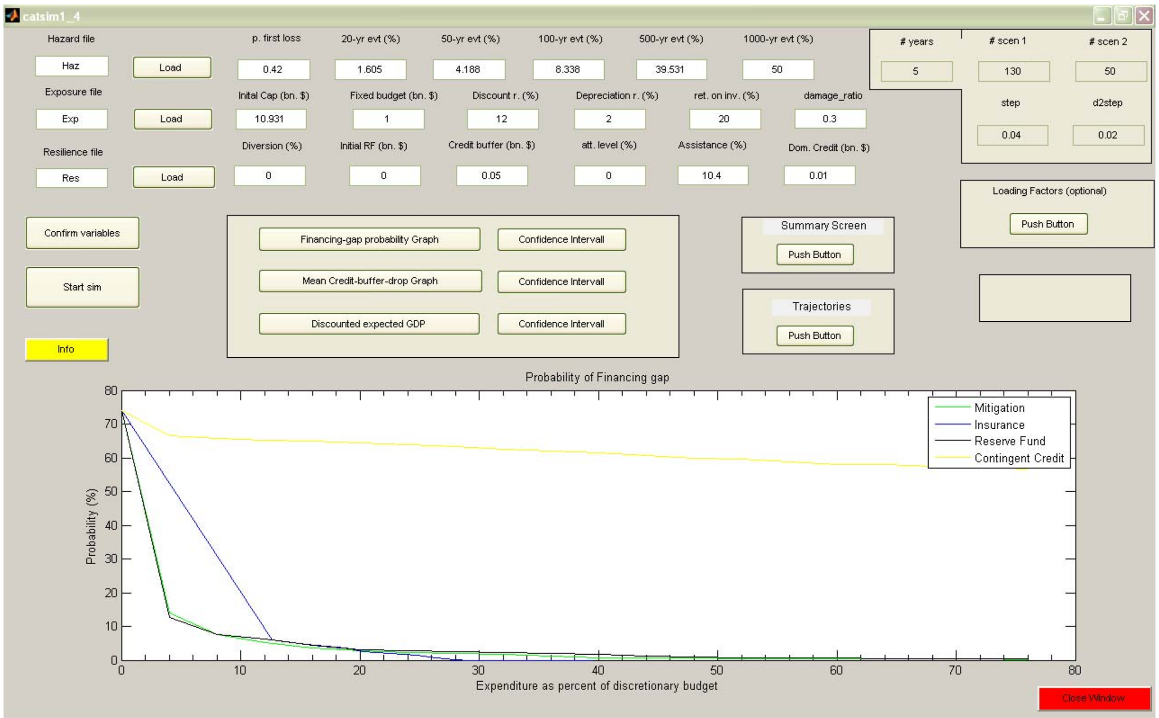


Fig. 17: Risk Management Strategies Assessment Window

Pushing the “Start sim” button will start the stochastic macroeconomic analysis. Dependent on the time horizon it takes 30 seconds till 2 minutes for the whole process to be finished (a pop up window appears which tells you when the calculations are done). You can then look at some of the results, including uncertainty analysis, e.g. one has to push on the different buttons in the middle of the window and if also confidence intervals want to be seen, one has to push the “Confidence Interval” button too.

In more detail, the Financing gap probability graph will show the probability that a resource gap occurs in the next years (defined by the time horizon) without and with the different risk instruments. The mean credit buffer drop will tell you how much you can expect to decrease your creditworthiness during this time period. Additionally, the discounted expected return plot will tell how much of taxes the government could expect during this time period without and with risk management strategies. Note, there is a trade-off between stability (e.g. decreasing the probability of a financing gap) and growth (e.g. increase of returns).

To have a complete picture of the whole analysis one can push the **summary screen** which shows the results in one window, including trade-off analysis, see the following window (Figure 18).

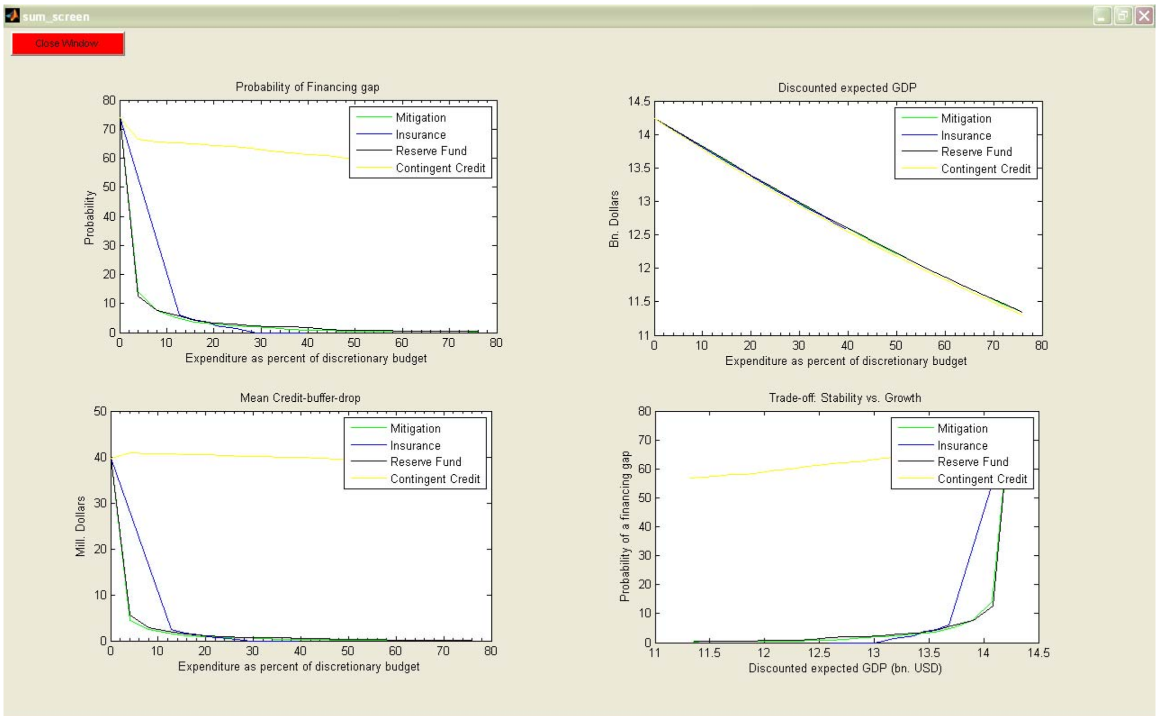


Fig. 18: Risk management summary window

There is also the possibility to look at some of the **trajectories** (e.g. the path of the economic variables for different scenarios) with and without ex-ante measures, just push the button called “Trajectories”. One example is shown in the next picture (Figure 19).

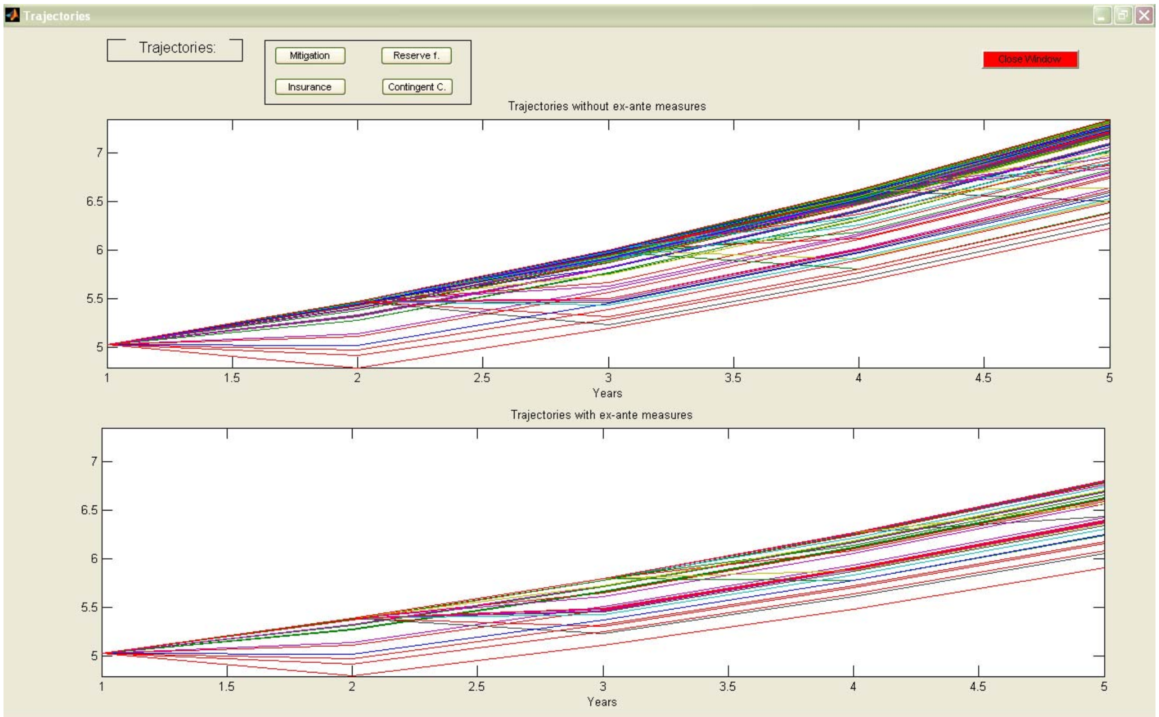


Fig. 19: Trajectories for selected growth paths with and without risk instruments used.

There is also the possibility to do a more detailed analysis of the insurance loading layers by pushing the loading factors button. However, this is only recommended for those with more interest in reinsurance XL-layer contract pricing (see Figure 20). For a detailed discussion see Mechler 2004 and Hochrainer 2006.

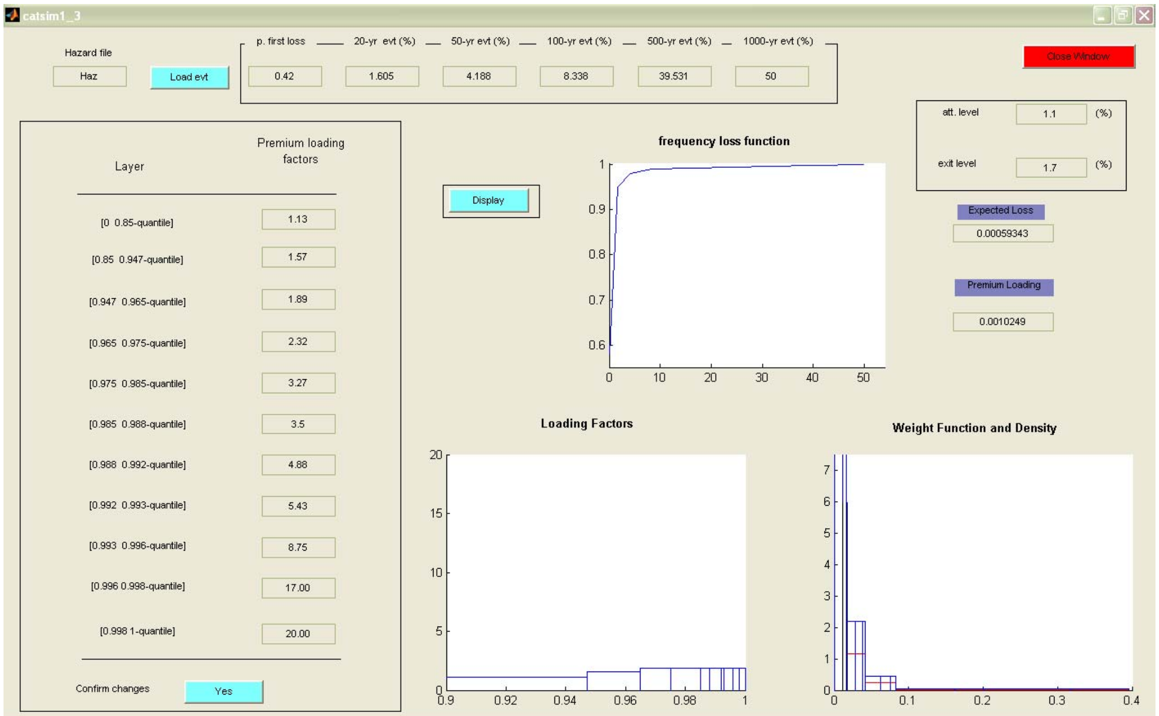


Fig. 20: Excess of Loss Insurance specifications.

Note: Usually in the first step, you first load up the files, then push the confirm variables button and afterwards the Start sim button. The figures appear after some seconds or minutes (depending on the time horizon) and after comparing and analyzing the results one usually wants to change some of the variables. After changing the variables one has to push again the confirm variables button and then the start sim button. Only pushing the start sim button would not change the results because the numbers for the variables are not recognized by the program yet.

5. Guidelines for a typical CatSim model run

Here, a typical example how an analysis could start and which things one has to pay attention to are given. The number in brackets refers to the windows in section 2.

- ➔ Usually, one starts with the main menu (Figure 8) and goes afterwards to the Vulnerability and Risk Assessment window (Figure 9)
- ➔ In this window one defines the direct risk and financial resilience and afterwards assesses the financial vulnerability and macroeconomic risk. First, one defines the direct risk by pushing the direct risk button to open Figure 10.

  - ➔ Window 10 opens if the direct risk button is pushed in window 9. Here, above the blue line, one puts in the file name, e.g. let's call the name of the file "Haz" and pushes the load button. Below the blue line he can also load and save a file, e.g. let's call the name of the file "Exp". Afterwards one can close the window by pushing the close button (red button). Hence, he looks now again at window 9 where he should now push the Financial Resilience button to open window 11.

  - ➔ Again in window 11 the user can load or save a file, e.g. let's call the name of the file "Res". He should again afterwards close the window by pushing the close window button (red button). He comes back again to window 9. There, he can now push the Financing gap analysis I or Financing gap analysis II button

  - ➔ Usually, the user has now three file names, which he puts into the upper right hand side. By pushing the load button the variables are uploaded into the Interface. Then one can push the **Optim_Calc** button to see the results. Afterwards one can change the ordering (left hand side) or the values of the variables in the upper middle side and pushing afterwards the **Optim_Calc** button again to look at the new situation. One can look at a specific financing scenario, e g. 100 year event by putting this value in the lower left hand side and pushing the optimal portfolio button. If the analysis is finished one should again close the window and start with window 9 where he can take a closer look at some financing gap issues by pushing the Financing gap analysis II button which opens window 14.

  - ➔ Here again, one has first to put in the file names, Hazard, Resilience, Exposure and push the load button. Afterwards, one pushes the **Gen Ex-post** button and looks and interpreted the results. (Note: First the files have to be loaded, afterwards the Gen Ex-post button has to be pushed.) Afterwards the user can change some of the numbers on the upper middle side and by pushing the **Gen Ex-post** button the new results with this setting are calculated. (Note: Only push the button once, because otherwise the calculation is performed several times or the system crashes due to calculation issues, you will know when the analysis is finished by a small window which appears afterwards). If the analysis is finished one should again close the window and push the GDP and Fiscal effects button to arrive at window 16 and look if the risk will cause also macroeconomic consequences. Afterwards, one should close this window and also window 9 because in window 8 the 'Financial Risk Management Analysis' button should be pushed to open window 17.

➔ Here, one again should type in first the file names, loading it by pushing the loading button and afterwards pushing the **Confirm variables** button, waiting till the calculation is finished (showed by a window) and then pushing the **Start sim** button. (Note: This analysis takes some time from 30 second to 3 minutes, so be patient, most of the time thousands of scenarios and their future consequences are calculated.) Afterwards, just push the buttons on the middle to look at the results. Note: You can also push the other buttons too, e.g. trajectories button to look at the development paths of the analysis: when doing that, be sure to close the window again. When you want to change some of the values of the variable, just put in the new numbers in the upper middle side and push the **Confirm variables** and afterwards the **Start Sim** button. If you have finished your analysis you can discuss the results again by looking at the other windows, e.g. 12.,14, and 16 etc.

6. Illustrative Example for a CatSim Analysis

Next, an illustrative example of a typical CatSim run with additional changes of parameters and discussion of consequences is given. The country under study is chosen to be Madagascar, however, the numbers presented here only serve as an illustration. We do not go into details already discussed in section 1, 2, 3 and 4 and directly begin with inputs and will focus especially on Figures 12 and 17.

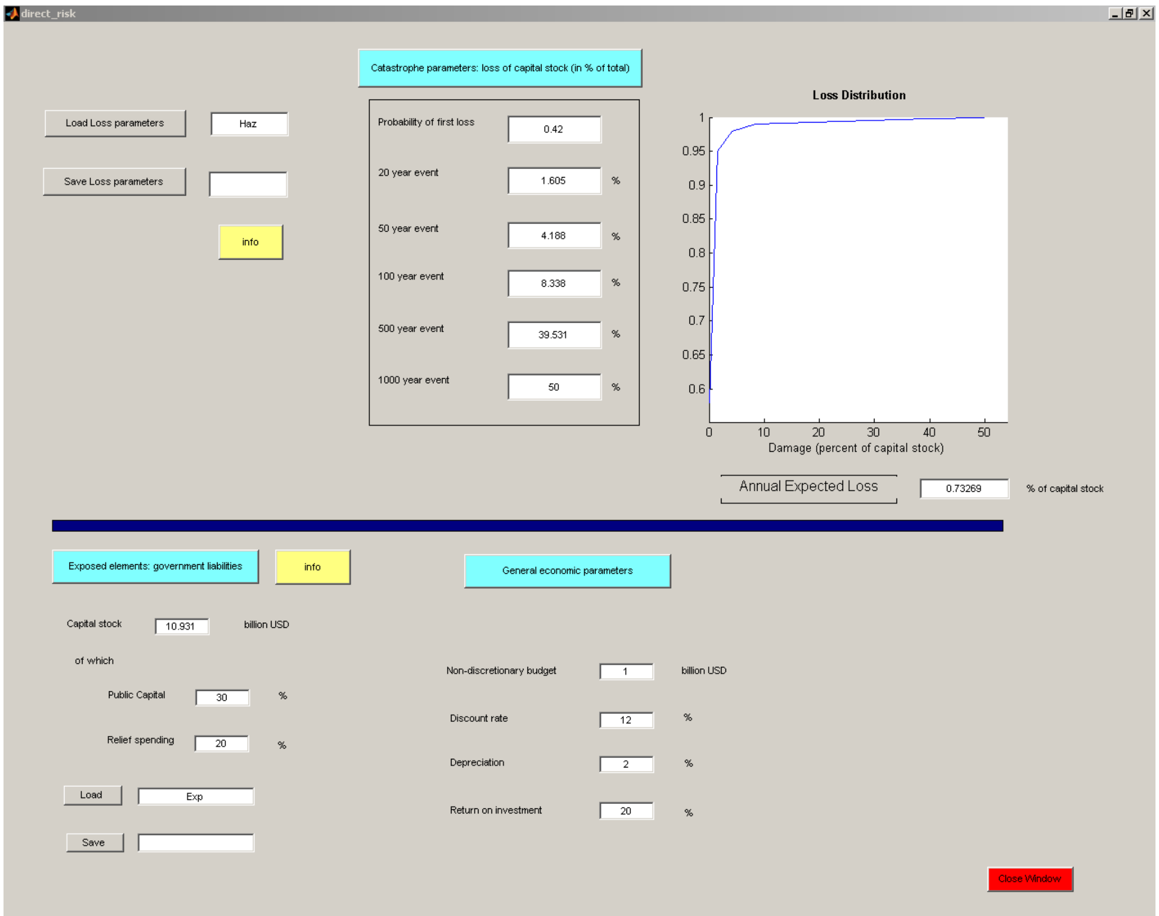


Fig. 21: Direct Risk Window.

The probability of first loss is 0.42 here, which means that with 42 percent annual probability losses due to cyclone events occur. Or conversely, with 58 percent probability no losses will occur. Additionally, conditional that there is a event which cause losses, the probability that the losses will be smaller than 1.605 percent of capital stock is 95 percent. Or in other words, with 5 percent probability losses will exceed 1.605 percent of capital stock, hence the word 20 year event as 1/0.05=20, i.e. a 20 year event will happen on average every 20 year. The same line of reasoning applies to the other numbers.

As said, the area above the loss distribution curve shown gives the annual expected losses, i.e. the losses one would expect to happen every year on average. Here, this is calculated to be 0.73 percent of capital stock. In other words, on average losses due to disasters will be around 0.73 percent of capital stock. However, this does not give any indication about the consequences and also not about the extremes which could occur.

Below the blue line capital stock is estimated to be around 10.931 billion USD. This is the total physical capital (public and private) of the country. In case of a disaster event the losses are separated into public sector and private sector losses. In the window it is defined that in case of a disaster event, 30 percent of the losses will be public sector related ones and additionally, the government is assumed to take 20 percent of the private sector losses too. Furthermore, the non-discretionary budget defines how much money is needed (in bn. USD) to keep up basic activities which are non growth related. The discount rate is needed to calculate the net present value of future assets, credits etc. The depreciation value will determine how fast stocks depreciate over time. Return on investment gives the amount of return from public investments (which are defined here as the total capital stock of the public sector). Next, we take a look at the Financing Gap Analysis I window (Figure 22).

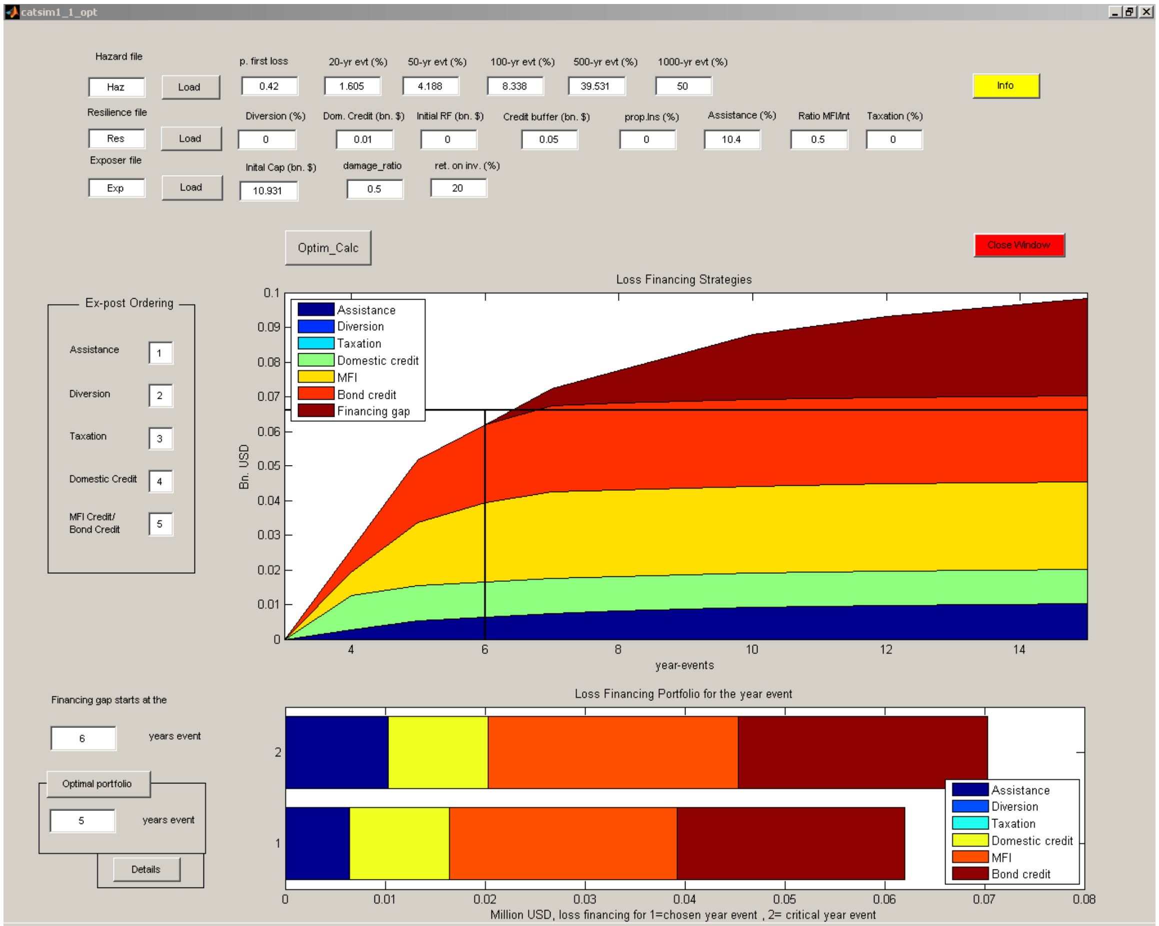


Fig. 22: Financing Gap I analysis.

The resources as discussed above would be enough to finance losses up to the 6 year event. For example, a 6 year event would cause losses of about 67 million USD, which could be financed by assistance (7 million USD), a domestic credit of 10 million USD, international borrowing and MFI credits with about 25 million USD each. However, each year event larger higher than the 6 year event would cause losses which could not financed fully anymore. For example, a 10 year loss event would cause a resource/financing gap of about 18 million USD. As one can see, the resource gap increases quite fast the larger higher the loss year events.

Lets now assume that the government will only finance public sector losses and no private sector losses anymore. Accordingly, one has to change the damage ratio from 0.5 to 0.3. Furthermore, also assume that the amount of money which can be taken from international finance markets is increased from 0.05 to 0.1 bn. USD. Additionally, assume that diversion from budget is possible of about 0.5 percent. Changing the parameters and pushing the Optim_Calc button will result in the following window.

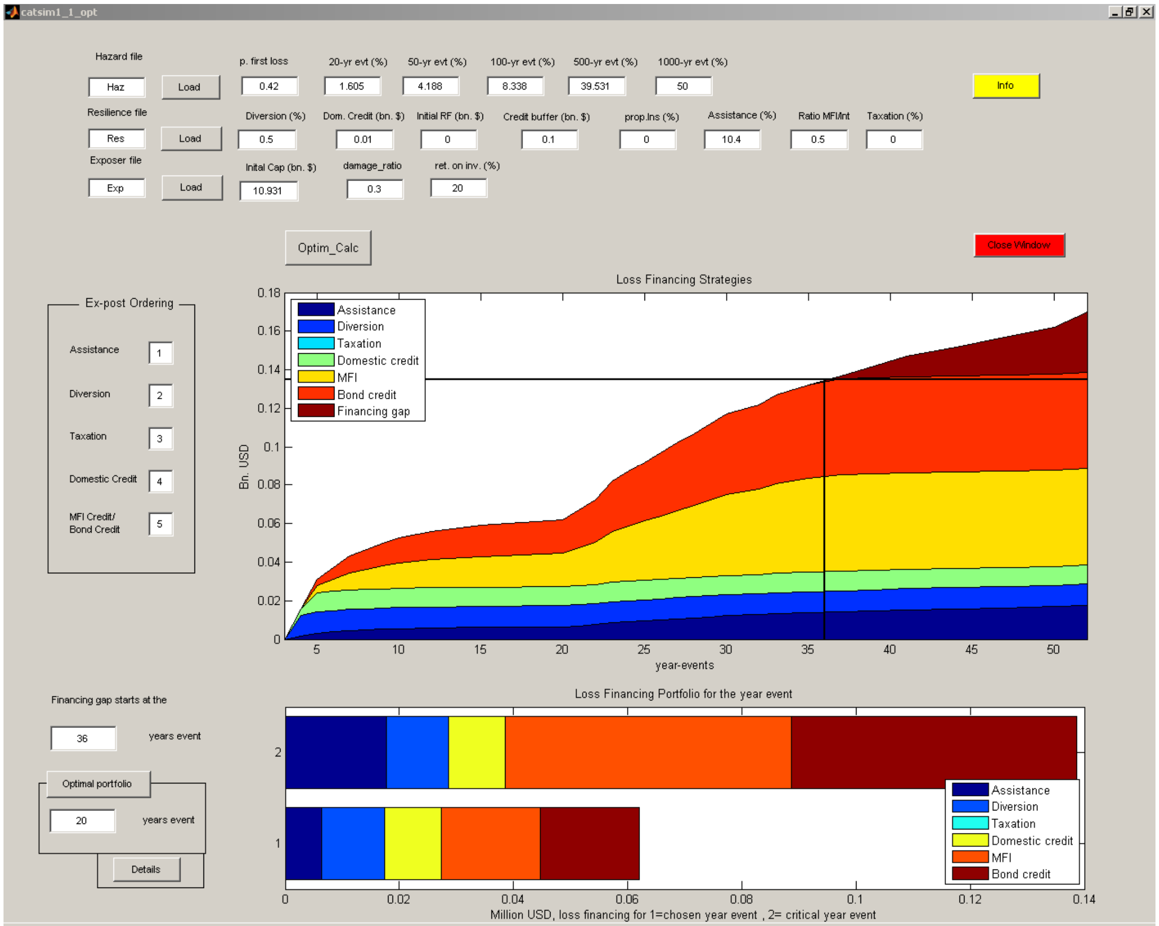


Fig. 23: Financing Gap I Analysis.

Note, the financing gap year event is now larger, which means a financing gap would happen with less probability. While in the former specifications a financing gap would have happened in the 6 year event it is now a 36 year event, i.e. one can expect that on average, every 36 years a financing gap would happen the next year. Loss financing comes mainly from credit arrangements but also diversion from budget (10 million) and domestic credit are important. Most importantly, as the government reduced its exposure to losses by 20 percent (no help to the private sector) lower risk levels are achieved. Other variables now could be changed again and sensitivity tests could be performed.

To see if the financing gap would cause long term consequences one could take a look at Figure 24.

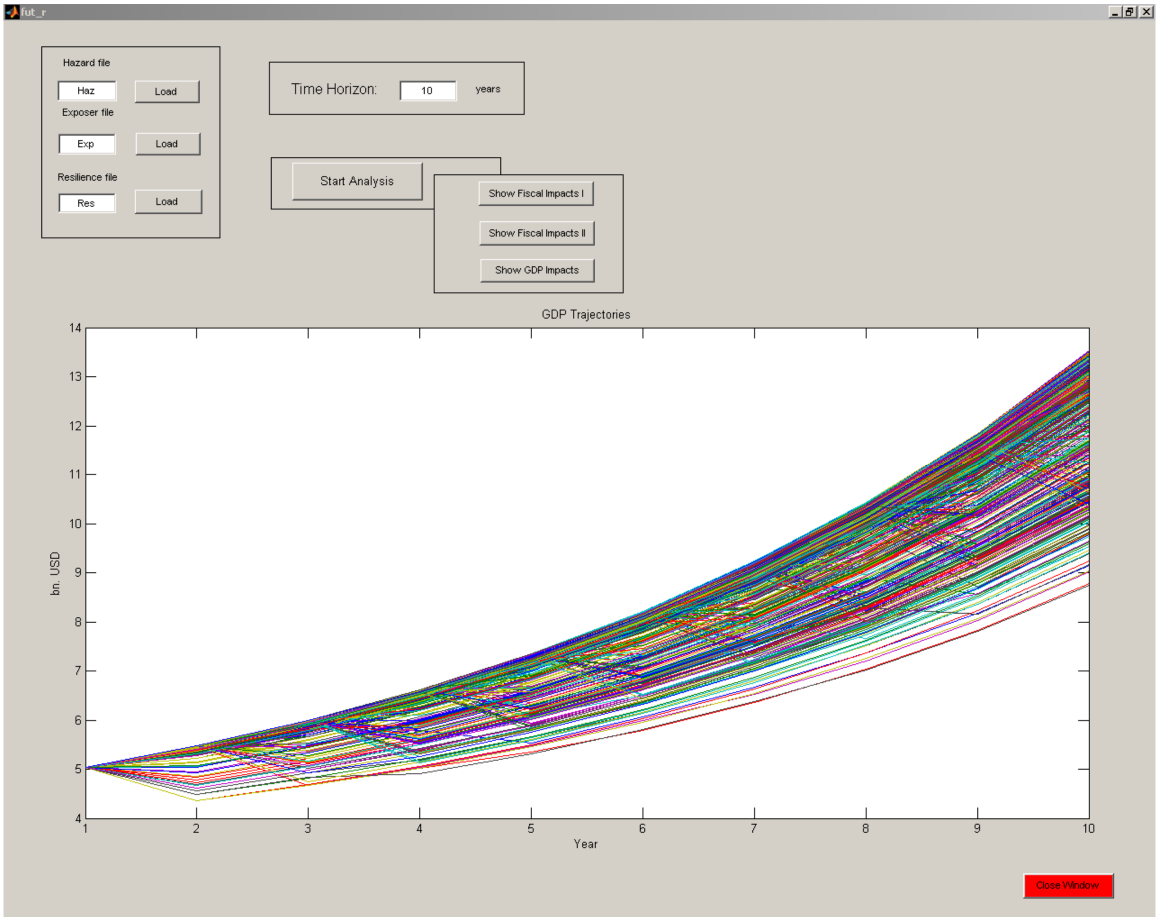


Fig. 24: Stochastic GDP trajectories.

Assuming the GDP to be 5 bn. USD (defined by the Capital stock, if it is assumed to be too low one can change this in the direct risk window) without any disaster events GDP could rise up to 13 bn USD in the next 10 years (again if the increase is assumed to be too high, one can change the parameters in the direct risk window, e.g. return on investment). However, disaster could cause declines dependent on their magnitude and occurrence. In the worst case scenarios GDP in the next 10 years would be only 9 bn. USD.

Note, all the different trajectories have a different probabilities. While the more frequent events will happen more often but will be less severe, most of the possible futures will be around the no event scenario, while some high impact events could cause dramatic losses. Additionally, there is the possibility that two consecutive rather small events could cause dramatic effects as resources may be depleted for financing the first event and no resources are available for financing the second one. All these possibilities are included. Hence, one could conclude from the picture that risk management may be beneficial.

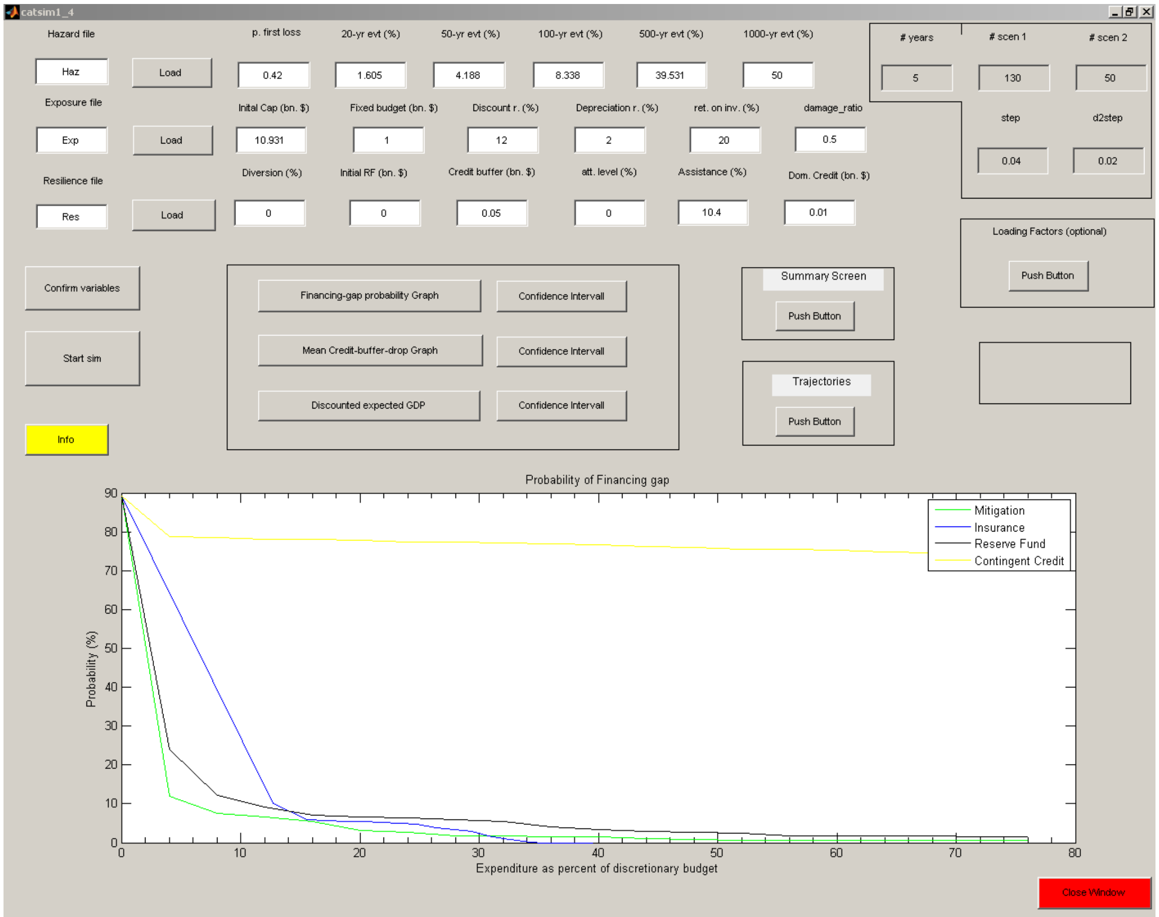


Fig. 25: Risk Management Analysis.

The Figure above shows the decrease in the probability of a financing gap (y axis) if investments in risk managements instruments are made. The planning horizon was set to 5 years. Hence, without any ex-ante instruments, the probability of a financing gap is around 90 percent. In other words, one could expect that in 90 out of 100 times in the next 5 years a financing gap would occur, or it is nearly certain that a financing gap will happen in the next 5 years.

Now assume that one invests 10 percent of the discretionary budget in risk strategies, e.g. mitigation, insurance, reserve fund or contingent credit arrangements. The probability of a financing gap would decrease differently for the different instruments. For mitigation it would decrease to around 9 percent, for the reserve fund it would decrease to about 11 percent, for insurance it would decrease to about 25 percent and for a contingent credit it would decrease to about 78 percent. Note, these results are very dependent on the input variables, e.g. for a lower efficiency factor for mitigation (Figure 5) things could change quite drastically. Hence, sensitivity tests have to be performed here extensively.

The mean credit buffer drop shown next will indicate by how much the creditworthiness would decrease in the next 5 years.

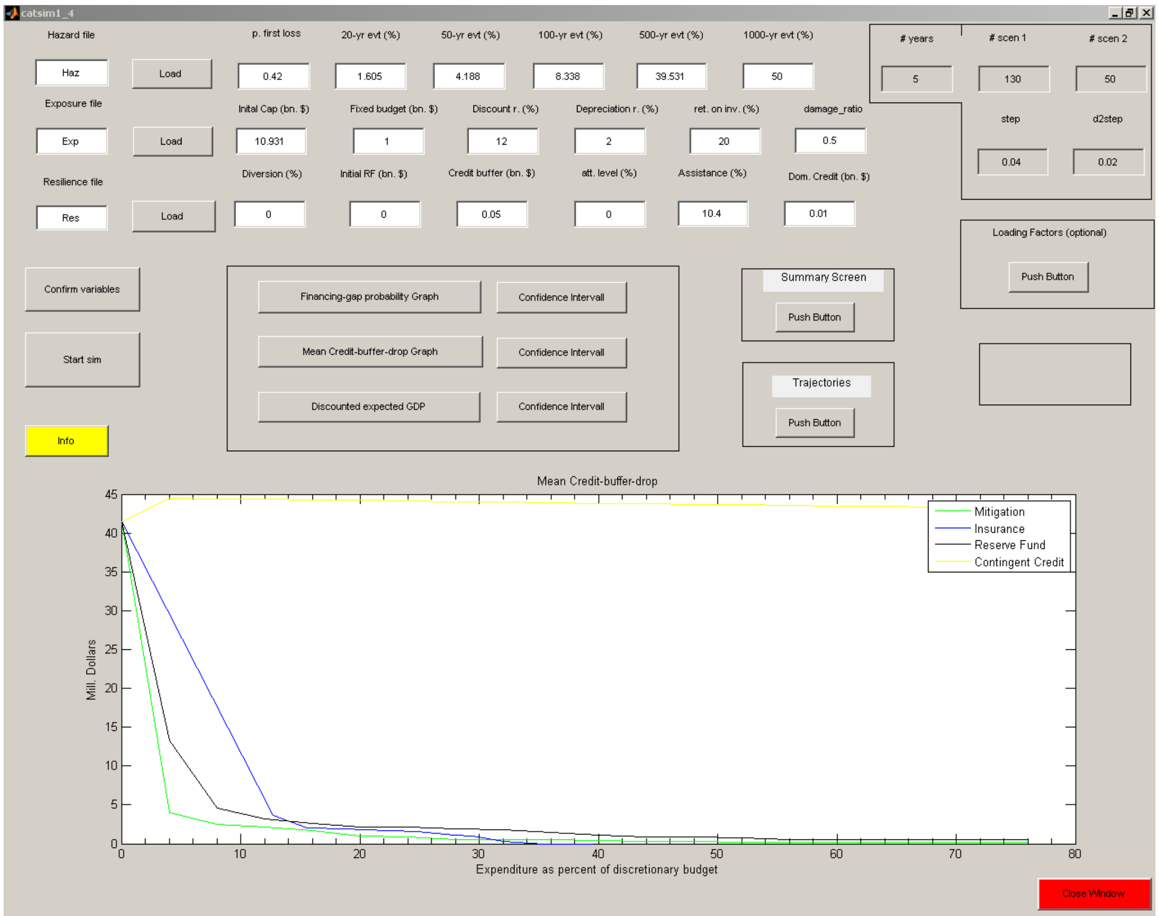


Fig. 26: Risk Management Analysis.

For example, while it is assumed at the beginning of the period that the government could borrow around 50 million USD, the expected drop without any instruments is large, i.e. about 42 million USD. Hence, creditworthiness would be reduced so that in the future only 8 million USD could be taken from MFIs or financial markets. This drop decreases quite fast if investments are taken into risk management instruments, .e.g. a 10 percent investment of discretionary budget them would decrease the drop by at least 30 million USD (dependent on the instruments). Note, as the contingent credit hedges the losses over time, this instrument would increase the indebtedness level and seems therefore less appropriate.

Gaining stability by decreasing risk would come with a price on growth, as shown in the next figure.

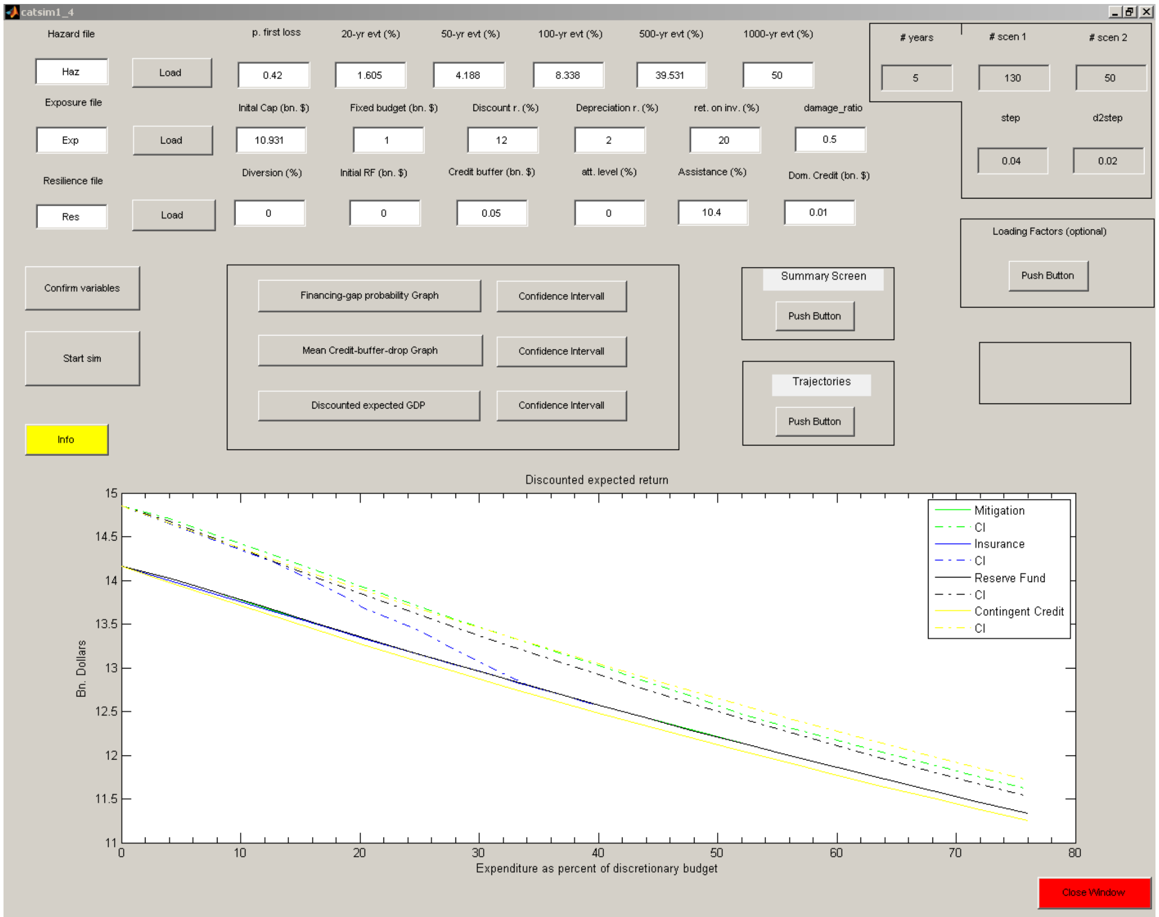


Fig. 27: Decrease in Growth Potential due to Risk Management.

The more one invests in risk management the lower the expected growth over time. Hence there is a trade-off between stability of fiscal and development paths and having a high growth trajectory. Discounted expected return would decrease if 10 percent of the discretionary budget is invested by about 0.5 bn. USD.

These different effects due to risk instruments now have to be looked at in the broader context of the given development plans. Afterwards, the analysis should be repeated again.

7. Calibration of Results

The best way to check if estimated parameters and input values used are (still) appropriate is to look at Figures 12, 13 and 15. Let's use again an artificial example. Assume, you have all estimated input parameters and want to check if they are still appropriate. You either can check them individually or go to the Financing Gap Analysis I interface (Figure 12). As described in chapters 4 and 6 first estimate the financing gap year event.

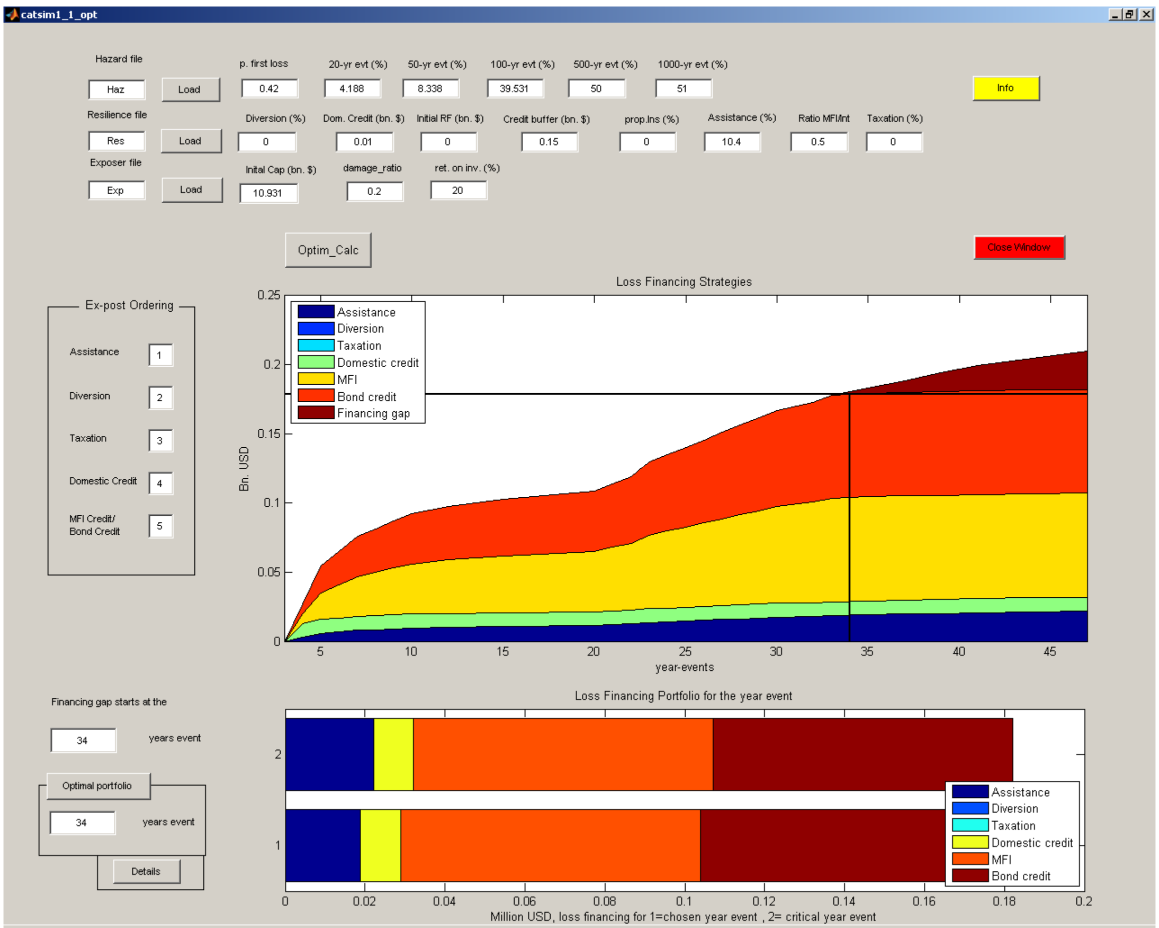


Fig. 28: Financing gap year event calculation

In the setting, as shown in Figure 28, the financing gap year event would be 34 (see the box on the lower left hand side). Now put this number to the optimal portfolio box (as shown in Figure 28) and click the optimal portfolio button. A graph already explained in chapter 4 and 6 appear. Now click on details and the following Figure 29 will pop up. On this Figure click the "show numerical results" to get the amount of financing resources (in bn USD) for the financing gap year event (i.e. where for the first time all money available has to be used and still not all losses could be financed).

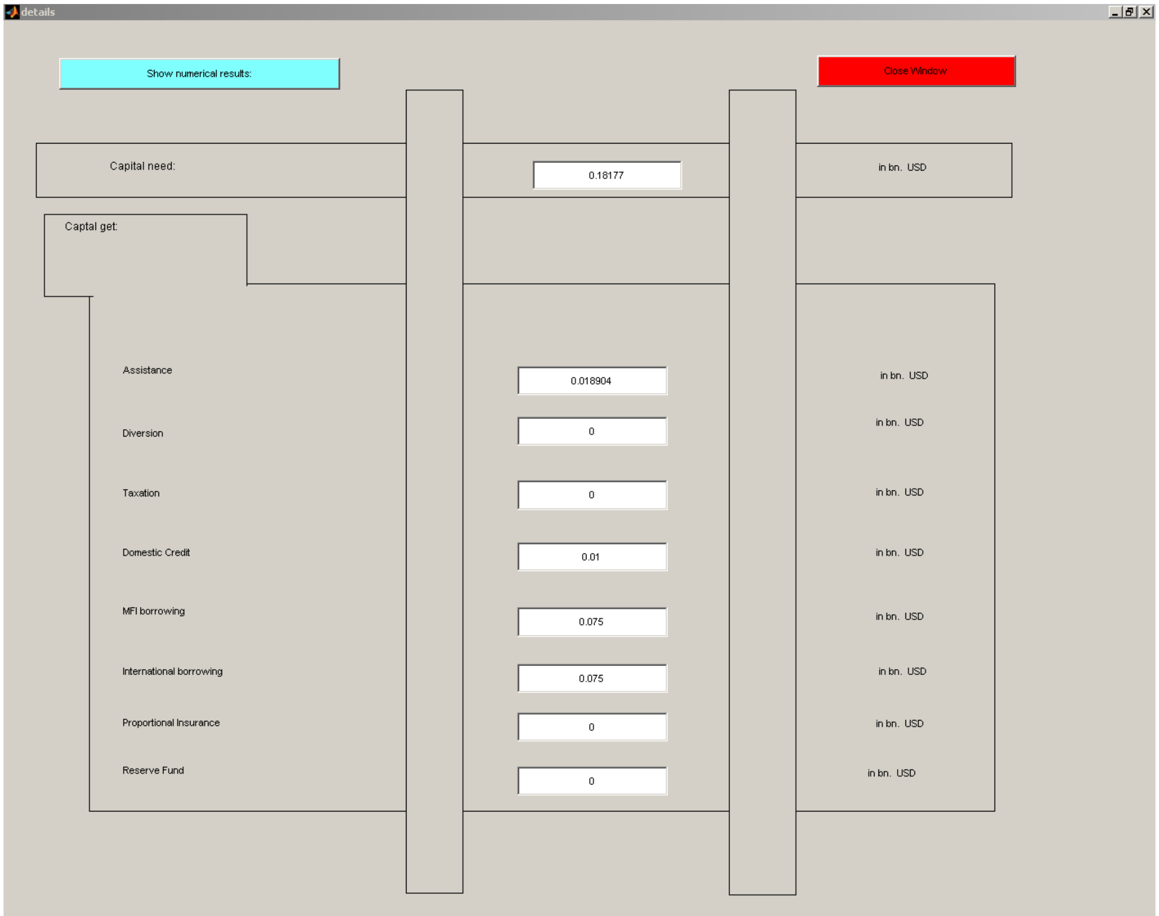


Fig. 29: Available resources for the financing gap year event

As one can see, the capital the government would need is around 180 million USD. This could be financed via outside assistance (19 million USD), a domestic credit of 11 million USD, and taking international credits of about 150 million USD. Note, it is assumed that this is the maximum amount possible to take from government resources. However, due to expert knowledge or a change in the financial/economic situation of the country it is actually the case that additional resources would be available or financing resources should be increased/decreased. For example, assume that 20 million USD could be diverted from the budget if necessary and 50 million of additional loans could be taken. One could now include this number in Figure 28 and perform again an analysis. However, budget diversion is in percentage of government revenue. To find the corresponding percentage of budget diversion to match the assumption of 20 million one should change the percentage accordingly and check the results in Figure 29. For example, to use 1 percent of the budget to divert it to finance the losses, would correspond here to be around 21 million USD, and 0.93 percent would yield the desired result (see Figure 30).

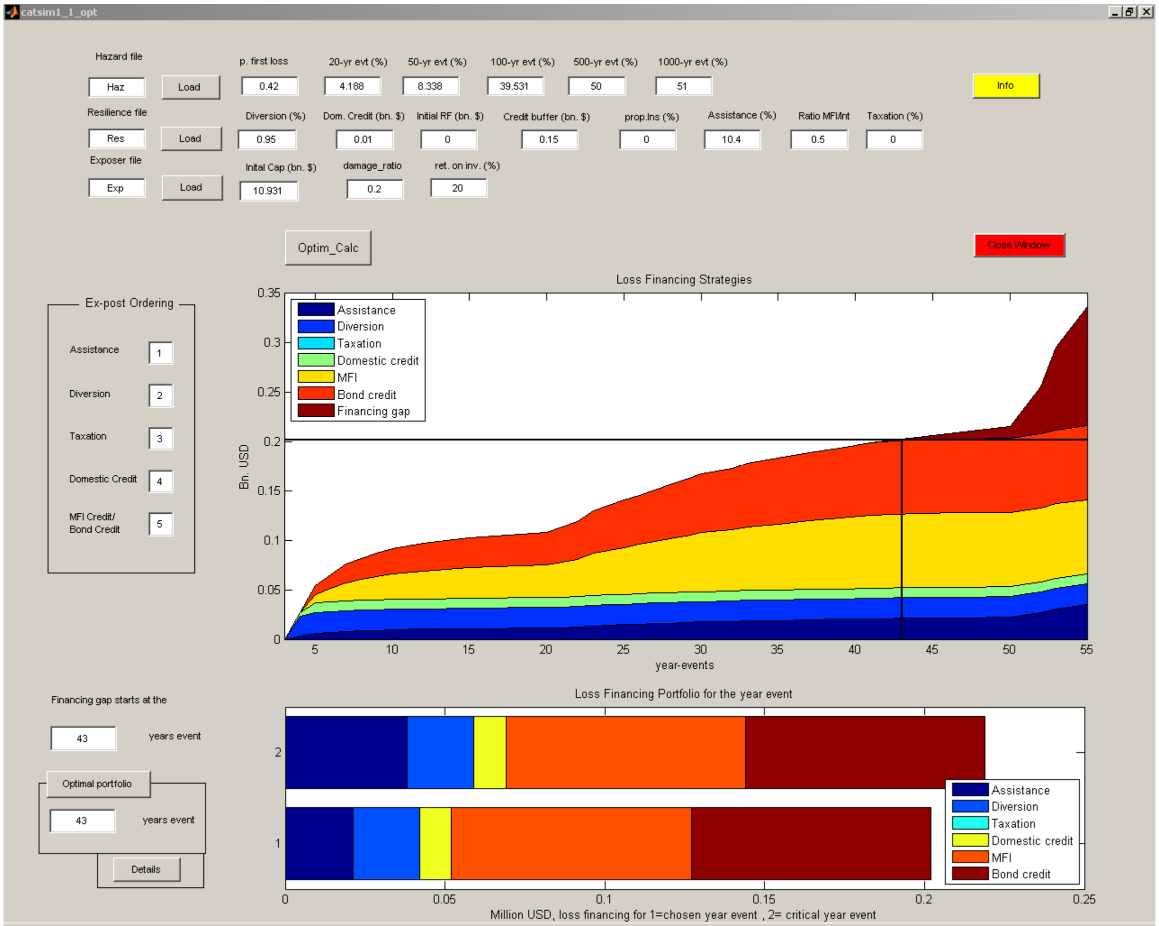


Fig. 30: Available resources for the financing gap year event (including budget diversion corresponding to 20 million USD, light blue bar)

This approach could be repeated till the results satisfy the perspective of the user what kind and to which amount resources are available. For a closer look on the results for other return periods, one simply could change the number in the optimal portfolio box, pushing the optimal portfolio button and looking again at the details in Figure 29. There is also the possibility to look at more than one specific return period by using the Financing Gap analysis II interface (Figure 14) and looking at Figure 15 which shows the financing resources for some selected loss return periods (see Figure 31).

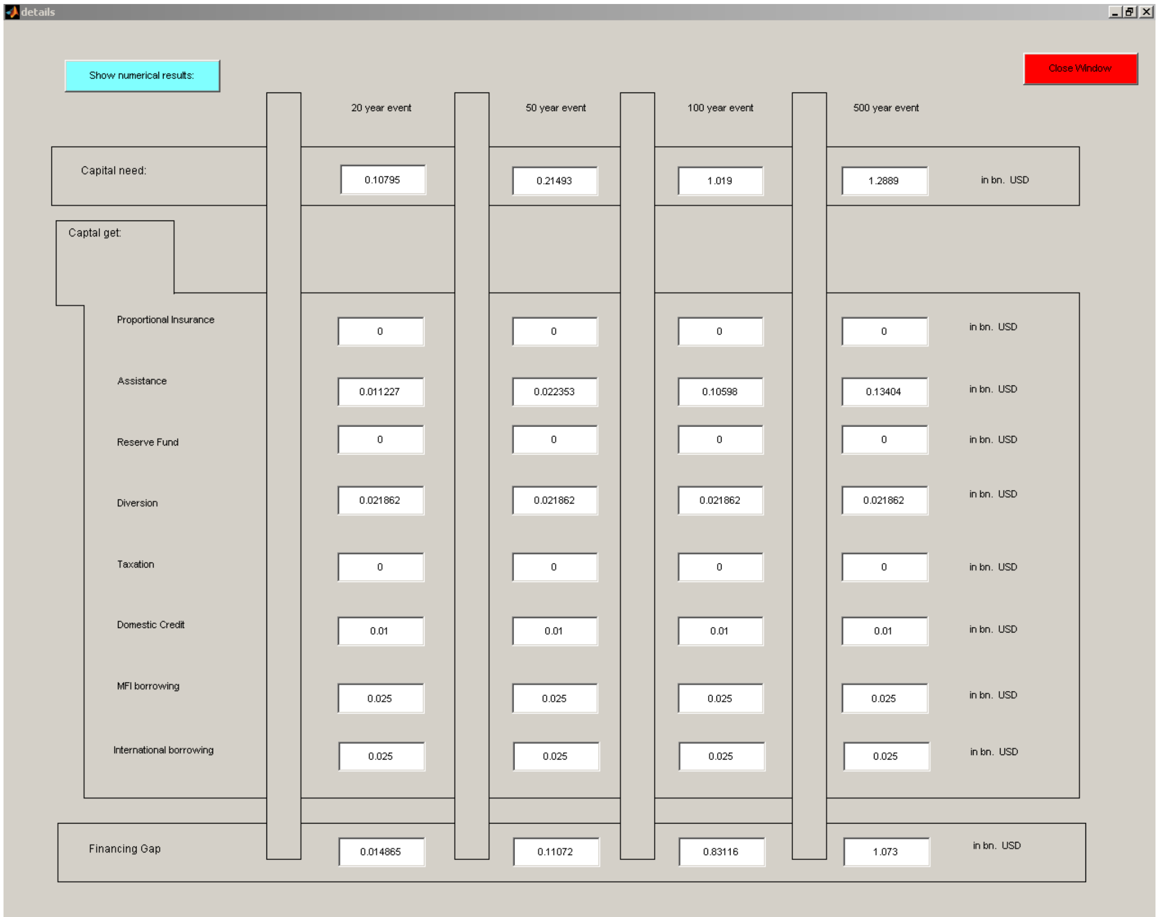


Fig. 31: Financing resources for selected loss return periods.

Here, it is also possible to check, if the given resources and its depletion are in the right order, e.g. for example assistance is used first to the maximum amount possible. Afterwards budget diversion comes in till the maximum amount possible, and at the very last credits are taken. If one wants to change the ordering this could be done in Figure 30 by changing the numbers on the left hand side under ex-post ordering.

On additional Figure is useful to calibrate the potential macroeconomic growth trajectories without disaster events (see Figure 32, which is the GDP and Fiscal trajectory window)

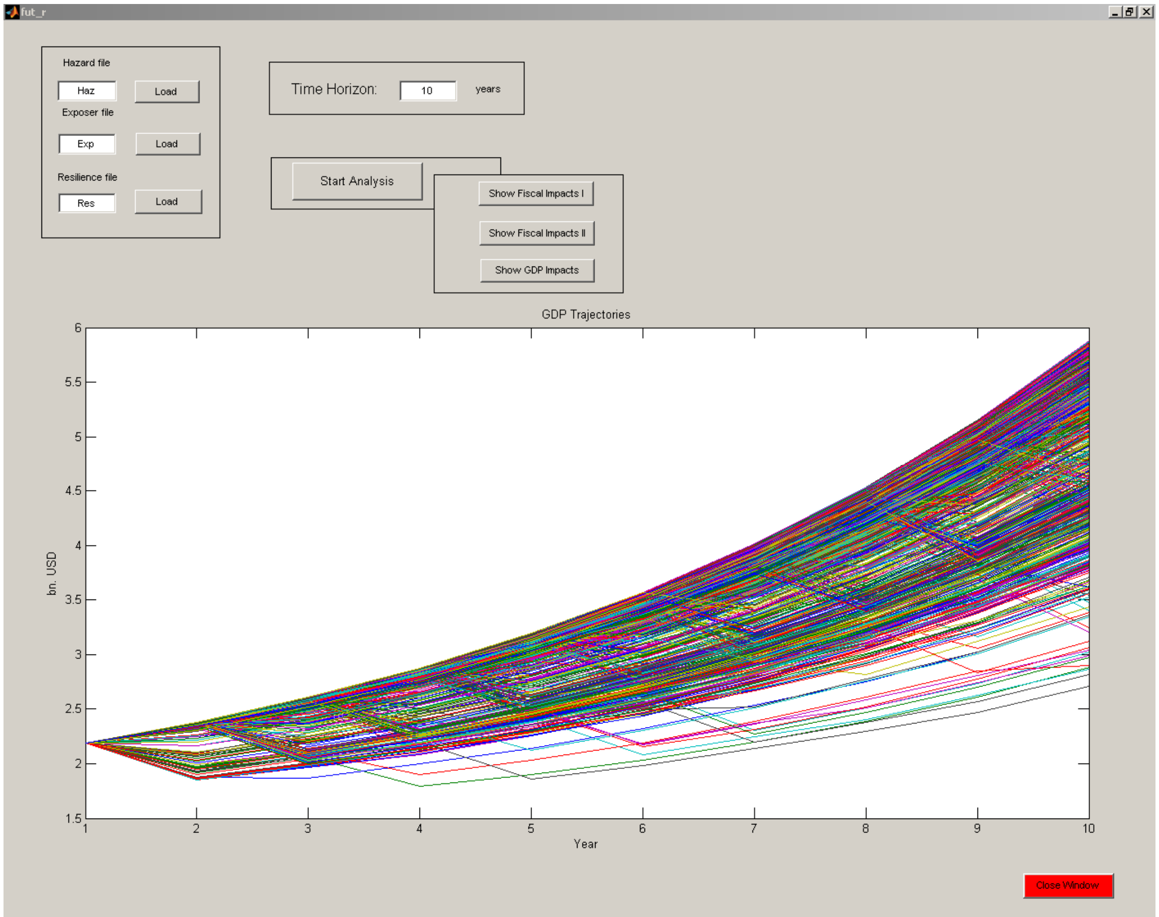


Fig. 32: Trajectories of macroeconomic growth.

The important trajectory which should be looked at here is the upper most one, i.e. going from 2.3 billion USD in year 1 to 5.8 billion USD in year 10. If this growth rate seems to high under the given circumstances one either can change the macroeconomic variables in the input windows (see chapter 3) and run the simulation again to test the results. The Figure 33 below shows the results.

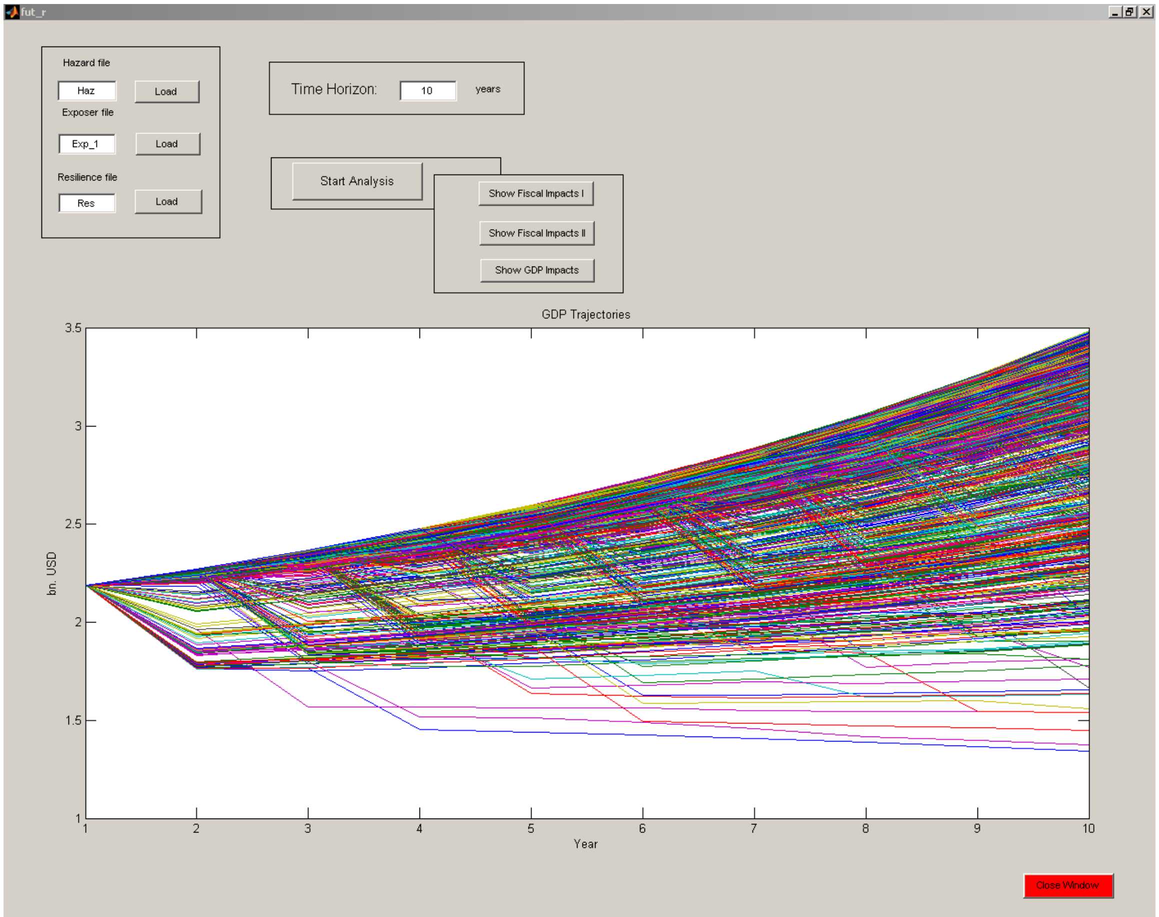


Fig. 33: Trajectories of macroeconomic growth.

Now, growth without disaster events is growing from 2.3 billion USD to only 3.5 billion USD. If this better reflects the potential future situation one could chose therefore the revised economic parameters.

It is recommended to start an iterative process to include uncertainties of possible growth and financing parameters. As discussed in chapter 4, one should always start with the current risk assessment and financing situation (steps 1,2 and 3 of the CatSim approach) and only after this assessment should take the next step and investigate possible growth reductions due disaster events and possible risk management strategies to avoid downside risk as much as possible while keeping an sustainable development growth path. As said, this has to be decided within an integrated approach where all possible stakeholders are included.

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